NEWSLINE

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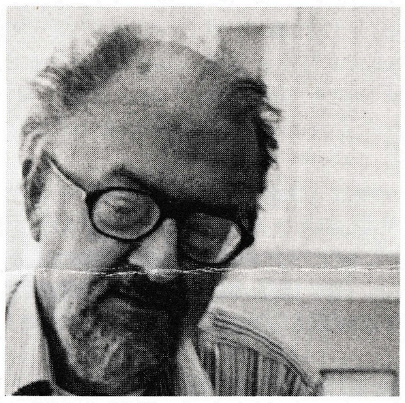
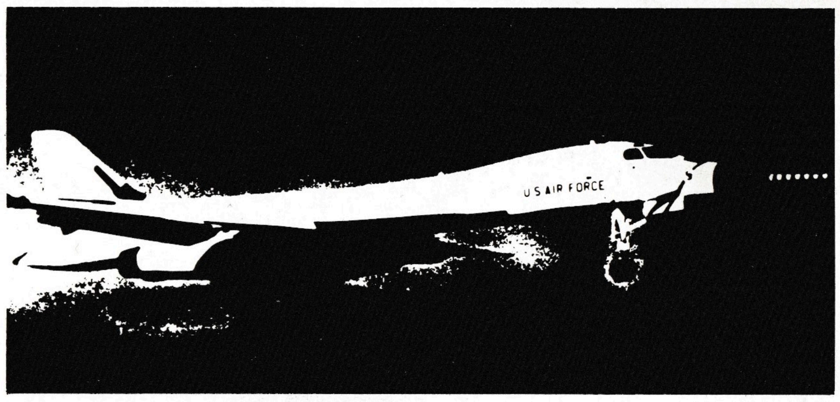
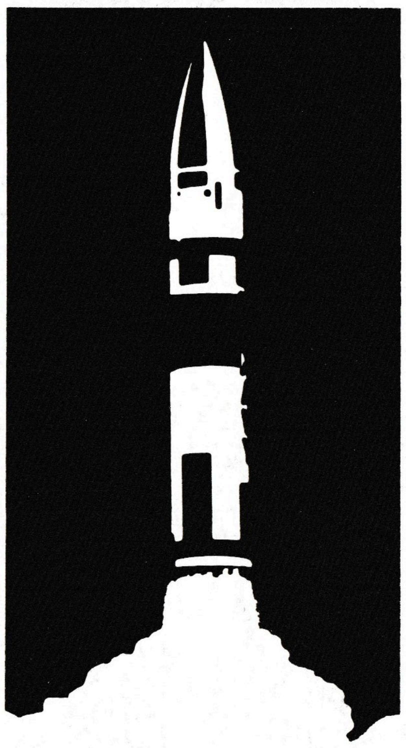


LLL's Weapons Program—Today and Beyond

In this special issue, Newsline looks at the purposes and guiding philosophies of the program, and some of the problems and frustrations of nuclear weapons work in the 1970's. We also take a look at the program's most important resource–its people–and their contributions. On our cover are just a few of the hundreds of people in the program: B-Division's Seymour Sack (top left); D-Division's Joe Taylor (top right) and Sydell Gold (center), and A-Division's Bill Shuler (bottom).





LLL's Weapons Program
Today and Beyond

In recent years, more emphasis has been given to what many term the Laboratory's peaceful programs—those related to energy, biomedical, and environmental research.

The illusion created by this growing emphasis is that the Laboratory is no longer focusing on its responsibility as one of the nation's two nuclear weapons design facilities and that the weapons program is fading in significance at Livermore.

Such is not the case. As readers of this special issue will find, the Livermore weapons program is, if anything, more important today than ever. And its people display a vigor, enthusiasm, and dedication that is in keeping with the significance of their responsibility.

In the fall of 1977 the Laboratory will complete 25 years of service as a national resource. There is no question that as LLL works its way through another quarter of a century, weapons research will still command a vital part of its effort.

According to Malcom Currie, director of defense research and engineering for the Department of Defense, we are witnessing the greatest deployment of new strategic nuclear missiles that the world has ever seen. He says this tremendous deployment of new missiles is being carried forward by the Soviet Union. At the same time the Soviets are adding to their submarine-based missile force, bomber squadrons, naval surface fleet, and ground forces.

The United States, while it has made steady improvements in accuracy and MIRV technology, and has a new SLBM, a new ICBM, and two strategic cruise missiles under development, has not made deployments to keep pace with those of the Soviet Union. The U.S. has also reduced its armed forces substantially and has fewer naval ships than at any time in the last 25 years.

In view of these events, the goal of the Laboratory's weapons program for some time to come will be to continue to help the nation maintain a credible, economical nuclear deterrent—one that will dissuade other countries from turning their might against the U.S., no matter how strong they feel they've grown.

Though people from all corners of the world would wish it otherwise, history has proven that "The price of peace is eternal vigilence." Why and how the Laboratory must continue to help maintain that vigilence by conducting its weapons program—in reality, the most peaceful of all its efforts—is the subject of this issue.

We begin this special issue with a roundtable discussion of the Laboratory's weapons program. The participants: Associate Directors Harry Reynolds and Rich Wagner, and Division Leaders Bob Barker, Bill Lokke, and Bill Nelson. Newsline recorded this discussion several months ago, edited the transcript, and updated it just before publication to keep it current.

NEWSLINE: It is no secret that in many parts of the public sector weapons work has evolved into something that is unpopular. Even at the Laboratory some people ask: Why is it important that this Laboratory remain so heavily involved in weapons research? Why don't we turn our good minds and dollars to solving the other important problems of the day—energy, pollution, transportation? Why is continuing weapons research needed?

REYNOLDS: The energy and other problems that you mentioned are certainly extremely important to the nation, and obviously we must deal with them. But I think the most important thing is that the nation have an adequate defense so that we can be assured that the citizens of this country will remain free and alive.

Nuclear weapons are, of course, a very important part of our defensive posture, and there are only two places in the country where the nuclear components of these weapons are designed. These are Livermore and Los Alamos. There is nobody else to do it for us.

There are, as we know, many laboratories and concerns throughout the country who can, and are, working on all of these other very important problems. This Laboratory can contribute to the solution of these problems—and will do so—but we have to keep in mind that our first and foremost responsibility is nuclear weapons R&D and the defense of the country.

WAGNER: Let me amplify some on that because Harry used the word "solution." I don't think there is a permanent solution to the energy, pollution, and similar problems...or the nuclear weapons problem. I think the "solution" is that you just have to keep working at those problems. This is because they are so complex. When things change in the world, or new technology comes along, or you learn something that gives you a different perspective on a problem, you've got to work it again.

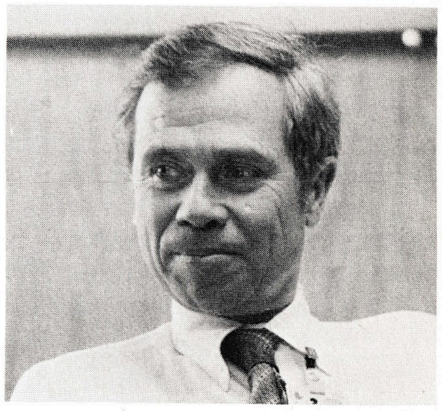
I think the model for energy work, weapons work, and national security in general is this: 'You are just going to have to keep working on these problems, decade after decade, doing the best that you can to insure that the economy, the national security, and so on, will continue in a viable fashion.'

LOKKE: Another related question that is often raised is, 'How much does national defense cost us?' Well, the dollar amounts may be deceptive. The relevant ratio may be the defense budget—and that portion of the budget involving nuclear weapons—versus the gross national product. If you strike that ratio—that is, not only money, but all of the resources, all of the people involved—we are talking about a small, decreasing fraction of the country's effort (Fig. 1).

NELSON: There is another pragmatic aspect of this situation that a surprising number of people at the Laboratory don't understand.

You asked before: 'Why don't we take our people and our dollars and apply them to the energy and other problems of the nation?' Everyone should realize that Washington dollars come to us for specific purposes. We don't have the freedom to redirect those dollars earmarked for doing weapons program work to other things. While the Director has certain latitude in the way he can do business, he cannot just take something authorized by the Congress for one specific purpose and direct it to something else.

REYNOLDS: The public tends to be concerned about energy and pollution because these things touch them closely. People are very aware of a gasoline shortage or if they are breathing polluted air. But we have to remember that the Soviet Union is expanding its armaments at a very rapid rate. Now this is not discussed in newspapers and television on a daily basis. Nevertheless it is happening and this country has to respond in a way that will discourage any overt acts of aggression on the part of the Soviet Union or other nations.



Harry Reynolds

The responsibility for the weapon design effort conducted in Livermore is handled by Harry Reynolds, a Laboratory associate director since 1967 and associate director for nuclear explosives since 1973. Reynolds, who headed the nuclear testing program here in the late sixties, has also served as a consultant on numerous civilian and military panels and is currently a member of the Scientific Advisory Group on Effects, and is scientific advisor to the Defense Science Board on Theater Nuclear Forces. Areas of research he has been involved in, in addition to weapons research, include atomic physics, heavy ion physics, and nuclear propulsion.

NEWSLINE: Is there any way that we can put the Soviet build-up into some sort of perspective?

BARKER: That's a recurring question and one subject to considerable debate. If you take a look at defense expenditures and military manpower over the last 10 years, you see a dramatic difference in the trend of money spent by the Soviet Union and that spent by the U.S., especially in terms of fractions of the gross national products of the two nations.

If you take a look at the statistics, you see the crossover in absolute dollars spent occurring around 1971 when Soviet military expenditures exceeded those of the U.S. And Soviet military manpower exceeded that of the U.S. even earlier—like in the late 60s (Fig. 2).

Those statistics are not ones you see in the papers very frequently. The

Soviet missile build-up is covered to some extent in the media, but it gets confused by the issue of overkill, a subject that really begs the question of Soviet intent. Now, it is very difficult to examine these trends and conclude that the Soviet Union will be content with anything less than military superiority over the U.S. Many people say it has already happened. I don't know. But we all agree it will happen unless there is a reversal in the U.S. defense spending trend.

WAGNER: My feeling is that a lot of the problem is generated by the closed nature of the Soviet society. You simply don't know what they are doing.

Generally, they have seemed to take the initiative in international politics and we have been in a position of having to respond, and in some ways that is an appropriate position for us. But that means we have to cover a lot more bases than they do.

They can decide on a direction to take politically, and in terms of the armaments they build, and devote all their efforts to that direction. But then it takes us a long time to discern what that direction is, and we have to be in a position to respond rapidly—which means we have to have a lot of technologies developed and ready to be built. That takes a lot of effort. When you combine the differences in our societies with the growing imbalance in military expenditures, you can see that we've got a really serious problem on our hands.

I have a quotation that I'd like to paraphrase. It comes from Dean Acheson back about 1947 when he was involved in getting us started on the policy of deterrence that we have followed all these years.

Acheson said that this country is finally faced with a problem that is of a different nature. The problems we had in the past were of the same kind that you have when you have a headache—you take an aspirin and it goes away. Past problems were short-term. The problem we have now—the security of our country in a nuclear world—is the same kind of problem as maintaining your health. It's something you have to worry about your whole life long. You can't stop.

NEWSLINE: Some people would say that we're in an arms race. Yet, it is known that you all feel we are not involved in such a race. Could you explain this?

Bill Nelson

During his 16-year Laboratory career Bill Nelson has held various positions in the Mechanical Engineering department and has been W-Division leader since 1973. His research time has been spent in investigating high explosives. In the mid-1950's, Nelson was a carrier-based jet pilot; he currently holds the rank of captain in the Naval Reserve.

WAGNER: I think there is a distinction to be made here. That is between building up ever more armaments in the sense of just steadily increasing numbers of weapons, and continuing to spend money in order to make what you have more responsive to the needs of the day.

Now if you want to call that latter one an arms race, then I suspect both we and the Soviets are doing that. But the former simply isn't going on in the U.S. although it is in the Soviet Union.

NELSON: I agree with Rich, especially about being responsive to today's needs. I think it's fair to say that something that was effective in 1950 is probably not effective in 1976. People tend to think that, 'Gee, we did all this once, why do we have to keep doing it?' The fact of the matter is that we have to keep doing it because the environment and technology changes, and that changes the things you need in order to survive.

WAGNER: Let me give you an example of how perceptions of the nature of the problem change, and how you then have to adapt to them. For the first 10 or 15 years after World War II the classic model of the nuclear problem was this: some day, without notice, there was going to be a giant strike out of the blue. Clearly, that's horrible to think about. We had to respond and the response we chose was to threaten a similar thing and built weapon systems accordingly.

In recent years we've come to think that that model is really incredible. It's incredible because you can't imagine what would ever get something like that started. So people in recent years have begun to think about the problem of crises and how they might develop.

When you think about that, you realize that the way it might very well start is not with an all-out exchange, all at one instant, but rather with localized conflicts and a few nuclear weapons. Perhaps it would go on like that for some time. Now the kinds of forces you need to insure that that situation doesn't get out of control are very different from the forces you need in the first case.

Rich Wagner

At the time this roundtable was conducted, Rich Wagner was head of B-Division, a post he had held since 1972. However, he has since been named associate director for nuclear testing. (George Staehle is now B-Division leader.) Wagner has been at the Laboratory since 1963 and has concentrated his research efforts on nuclear explosive design, weapon effects, and ABM system studies.

REYNOLDS: What Rich is bringing out is that we aren't just building more and bigger weapons. The total yields in our

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About this issue

Squire

It was a crisp November morning as Newsline *writers Martin Gottlieb and Dale Sprouse steered their rental car along the expressway toward ERDA headquarters. This was their first visit to Germantown, Maryland, but that wasn't the reason for the twinges of apprehension they felt. Rather, it was the nature of their assignment.*

Gottlieb and Sprouse had been sent east to begin work on this special issue of Newsline. *Because nuclear weapons development is one of the least publicized areas of work in the total ERDA operation they weren't sure how far they would get with this particular project. But as you will see in reading this issue their trip was, indeed, successful.*

During that trek to the Washington area Gottlieb and Sprouse interviewed ERDA officials as well as former Lab people who are gaining a new perspective on weapons work from experiences with private consultants, the Defense Department, as well as assignments at ERDA headquarters.

Those interviews provided vital input to Sprouse's account of some of the Lab's contributions to the nation's stockpile and were crucial to his consideration of future directions for nuclear weapons research.

From Washington, too, came much of the information for Gottlieb's stories on arms controls, as well as his vignette on Joe Landauer's hectic stay at the Pentagon.

Another Newsline *writer, Jack Saunders, had to do some traveling, too. He had to make several trips to Nevada to cover a single underground experiment from start to finish. He survived the tedium of three postponements to file his report. "I felt like I was in an old movie playing the part of an expectant father," he said.*

The other articles in this issue were based on interviews conducted locally. These include Saunders' study of Edward Teller's impact on the weapons program, Gottlieb's report on what it's like to be a weapons scientist and his explanation of the weapons production complex, and Sprouse's story on the interaction between the Lab and the military. Ken Rhodie conducted the roundtable discussion with weapons program leaders.

These are the writers of this special issue but they are by no means the only people who contributed to its development. There were many others in the weapons program who helped considerably. Special among these is Robert Squire who counseled, and when necessary consoled, the Newsline *staff, and provided technical assistance where needed on this very complex subject.*

Bob Squire has been with the Laboratory in various capacities in the weapons program for some 18 years. Most recently he has been a staff assistant to Harry Reynolds; by the time this issue is published he will have moved to Washington to begin a two-year assignment in the Pentagon. He replaces Joe Landauer who has returned to Livermore (see page 15).

The Editors

stockpile have been going down (Fig. 3), and we are involved in an entirely different set of tasks. One very important job is simply increasing the safety and security of our weapons. Also, they need to be more militarily effective and less damaging to non-military targets.

Fred Ikle, who is head of the Arms Control and Disarmament Agency, put it very well when he said: "I am optimistic that more imaginative designs in nuclear arms can still make major contributions to our arms control objectives." That's part of our objective at the Lab.

BARKER: The dollar crunch we have seen in the nuclear programs also shows up in our total defense budget—so it has had its effect on conventional forces as well.

For instance, in Europe, we and our NATO allies see no way of affording a conventional force big enough to deal with the conceivable extremes of Soviet strength. Therefore, the nuclear force in NATO Europe constitutes a deterrent against those extensions of the threat that are beyond our conventional capability.

And Rich made the point, the nuclear forces you need to provide a real deterrent in those circumstances are considerably different than those that you need for a strategic deterrent.

NEWSLINE: One reason people tend to be uninterested in more weapons research is that the work seems to cost so much. Could you comment on that?

REYNOLDS: One often hears the point that the country could save a lot of money if we weren't working on nuclear weapons and that we could use the money on other things such as energy, or what have you. I think it's not too difficult to prove that what we do here at the Laboratory in nuclear weapons work does provide an effective defense at a much lower cost than if we weren't doing this kind of work.

NELSON: An excellent example is the Polaris submarine. It would have been very expensive if this Laboratory hadn't discovered the means for making the missile payload powerful yet small enough to be carried by a submarine. Getting that payload to a specific point on the earth is a very expensive thing to do. And if we can make the payload smaller, lighter and able to do its job more effectively, this saves money in the overall system.

NEWSLINE: That is a good example but it is something we have done. The question is, what is there to do now?

WAGNER: The perception on the part of some people is that what we do is essentially just more of the same—building more weapons, or testing existing designs to see that they still work.

In fact, that's a wrong perception. The sorts of things we work on are often really qualitatively different. There is a whole list of designs that are possible in principle—they would conserve energy and momentum, and obey the other laws of physics. But they are so complex that we haven't been able to achieve them yet.

If you look at many of those ideas, they are things that can give us a more stable deterrent and make our forces more survivable or more secure. We are working hard to try to realize those things so that we have options in the future.

NELSON: Exploring the boundaries of our technology accomplishes two things. First, we make sure that the other guy hasn't found some new breakthrough that will revolutionize warfare. And it helps us to neutralize what the other guy has.

NEWSLINE: What things are particularly disappointing about the weapons program?

WAGNER: I think one thing that's been disappointing over the last decade or so is that we have, in fact, demonstrated the feasibility of a lot of designs which are applicable to the tactical weapons stockpile, but they have not been picked up on and built.

Bob Barker

Barker joined the Laboratory in 1966 and has served as D-Division leader since 1973. His research has involved him in atomic physics, nuclear weapons design and theory, and the military application of nuclear weapons.

It's frustrating because for years now we have known how to make designs which would be better deterrent weapons. But it has just been recently that we've been able to work on them. The Lance warhead that was put in the stockpile recently and the artillery shell that we are working on are steps in the right direction. But they are years late.

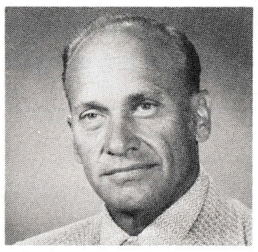
REYNOLDS: What we're saying is, we have many ideas that we and the DOD think are important to our defense and are necessary to get into that stockpile, but that our real disappointment is that our budget has been eroding to the extent where we simply can't finance the effort to follow up these better ideas. Now all of the laboratories, together with ERDA, have been working very hard on turning around this budget situation and I think we are making some progress.

NEWSLINE: Is there any evidence of that?

REYNOLDS: Yes there is. The ERDA Administrator has asked for and received a significantly larger weapons budget for the Laboratory for Fiscal '77 than we have had for some time. That is a real sign that we're being heard and that the need for our efforts is recognized in ERDA and also in the Department of Defense. But I think what is more important is a growing awareness throughout the nation that our defense must be supported with more vigor than in the recent past. This has become a campaign issue which will stimulate much interest and debate in the next several months.

BARKER: You know the U.S. did have a significant strategic advantage over the Soviet Union at one time. That disparity of strategic forces did not escape them and all the evidence points to the fact that the Soviet Union decided it was not going to let it remain that way. What's disappointing is that some people forgot why we are at this Laboratory—what our purpose is and what our function is and the Laboratory's capability eroded as a result of the annual gnawing away at the budget.

It was only in the last two years that we sat down and took a hard look at what those little 10 percent reductions meant in total. We realized we had to make it clearer what capabilities had been lost, that there was a significant



Roger Batzel comments on LLL's future in the weapons business

For some two decades the advances made in nuclear research and development by the Lawrence Livermore Laboratory have been a major factor in maintaining a strong U.S. defense posture. Arms control negotiations relating to nuclear weapons have been conducted for almost as long a period, and they are continuing. Our success in maintaining the strength to be free and to negotiate rests on future research.

Our country, our Laboratory, and each of us as individuals, face a future with some uncertainties. The closest thing to certainty, in my mind, is the continuing need of our country to maintain its military strength. To meet that need, the U.S. will look to the Livermore weapons program for a long time to come. We must not lose sight of the fact that our central job must continue to be the weapons program. Nuclear explosives is still a young field. Much remains to be learned, and only exploration can prevent surprise and provide options. Old weapons systems need to be replaced; new ones must be safer and more effective.

Research and development are the first line of future strength. I believe our weapons program— and the creative people in it—will continue to make a difference, for our country, in the world of the future.

Roger Batzel

Bill Lokke

A Laboratory career that dates back to 1957 reached a high-point for Bill Lokke when he was awarded the E.O. Lawrence Medal on February 12. Lokke, who has been A-Division leader since 1973, was paid ERDA's highest honor for his work on the Spartan ABM program and weapon physics advances. Lokke's research at the Laboratory has been devoted to theoretical weapon physics code development, nuclear explosive design, and weapon effects.

degradation in capability and that it should not continue unconsiously. If it did it would, in essence, constitute a major redefinition of the Laboratory's role.

Of course the situation is broader than the nuclear laboratories. It goes across the total defense structure.

NELSON: It used to be that the weapons money sort of came on schedule as needed. It isn't that way anymore. Now, all of us spend a great deal of effort explaining the severity of the problem and the size of the changes we need. It's a new way of doing business. It means that you not only have to convince ERDA, but also Congressional staffs, the DOD, and others. We have to be sure we are getting the story to the right people. We think we are making progress.

BARKER: I think it's an appropriate role. I think that we ought to know why we need the money we say we need, and that we must be able to articulate it to anybody who asks. It's been a healthy process for us.

NEWSLINE: We've talked about public apathy, criticism in the media—things that could affect people's morale. How do you see people's morale in the weapons program?

LOKKE: I would say, speaking for A-division, that the answer is we are enthusiastic. But let me quickly add a very important constraint. At the moment, there is a frustration caused by the fact that we've had to limit our tests in the last year or two to essentially those programs that won't be permitted now that the Threshold Test Ban has taken effect (Ed. Note: See "Arms Control" story in this issue). This means that a number of our people who are eager to work on other weapon ideas don't have a test opportunity right now because of the backlog of things that must be done. They have to either work on the programs that are being supported and not work on their own, or simply make do with very limited resources—no tests, much less computer time, etc. That sort of thing cannot go on forever, or we are bound to suffer in a morale sense.

REYNOLDS: I think morale is high because we've got a lot of ideas to work on that are going to be very important to the country. We understand better just where our efforts fit into the national picture and national defense. I think our resources are going to increase.

ERDA's Edward Giller discusses the strategic power balance*

For over a decade, the strategic balance of power has been moving steadily in the direction of the Soviet Union. Between 1965 and 1975, the Soviet Union erased most of the quantitative advantages of the United States in strategic nuclear weaponry.

The Soviets pulled ahead of the United States in strategic nuclear weaponry. The Soviets pulled ahead of the United States in numbers of deployed Intercontinental Ballistic Missiles, in total missile throw weight, megatonnage, and megaton equivalents, and in the total number of strategic delivery vehicles.

In numbers of warheads and in heavy strategic bombers, the United States maintained a quantitative lead.

While the Soviet thrust during 1965-1972 was primarily quantitative, their post 1972 qualitative advances are striking. They have introduced sophisticated Multiple Independently Targetable Reentry Vehicles (MIRV) systems and warheads. Soviet progress in accuracy has been very substantial and it seems there will be rapid progress in the near future. Their R&D program is extremely aggressive and is beginning to pay substantial dividends in improved weapons performance.

The Defense Department now projects that by 1980 the Soviets will have eliminated the U.S. lead in the number of missile warheads. The average Soviet MIRV yield will be about three times the highest U.S. MIRV yield, resulting in an overall Soviet missile force equivalent megatonnage superiority of three to one....

**Excerpted from a speech by Edward Giller, ERDA's deputy assistant administrator for national security, at Vandenberg Air Force Base in April, 1976.*

THE PERCENT OF THE U.S. GROSS NATIONAL PRODUCT DEVOTED TO DEFENSE HAS DROPPED TO THE LOWEST IN TWO DECADES

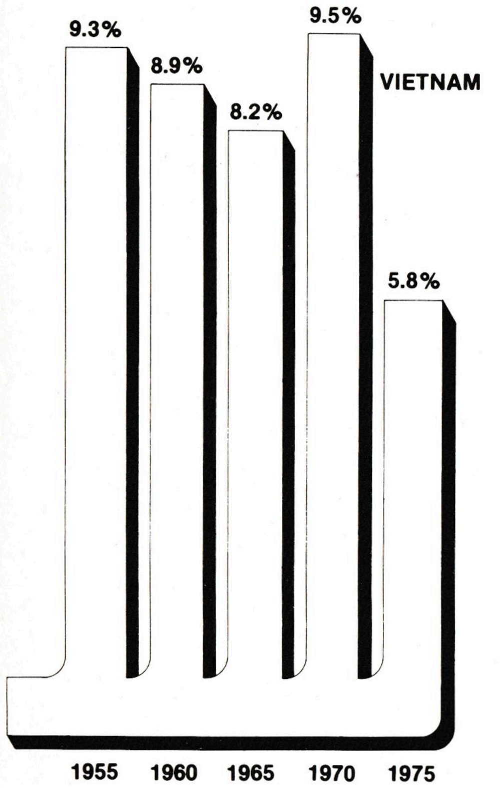


Fig. 1

(Source: FY '76 annual Defense Department report to Congress)

SOVIET—U.S. DEFENSE EXPENDITURES & MILITARY MANPOWER

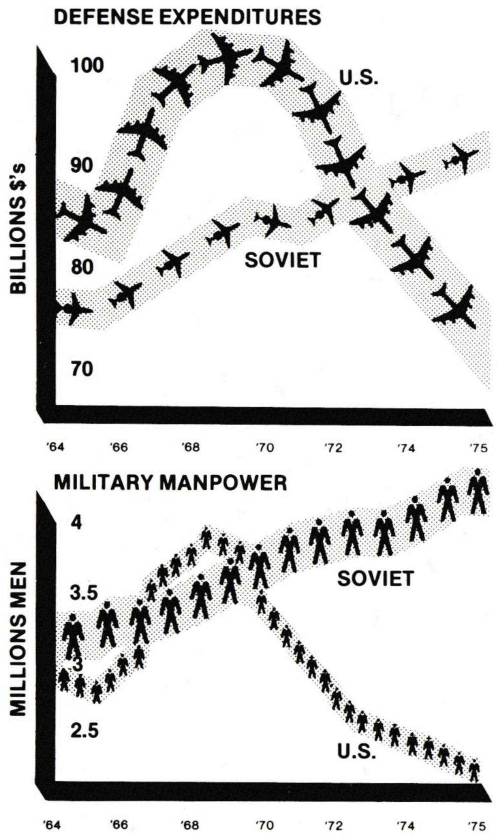


Fig. 2

(Source: FY '76 annual Defense Department report to Congress)

THERE HAS BEEN A STEEP DECLINE IN THE STRATEGIC FORCE TOTAL YIELD

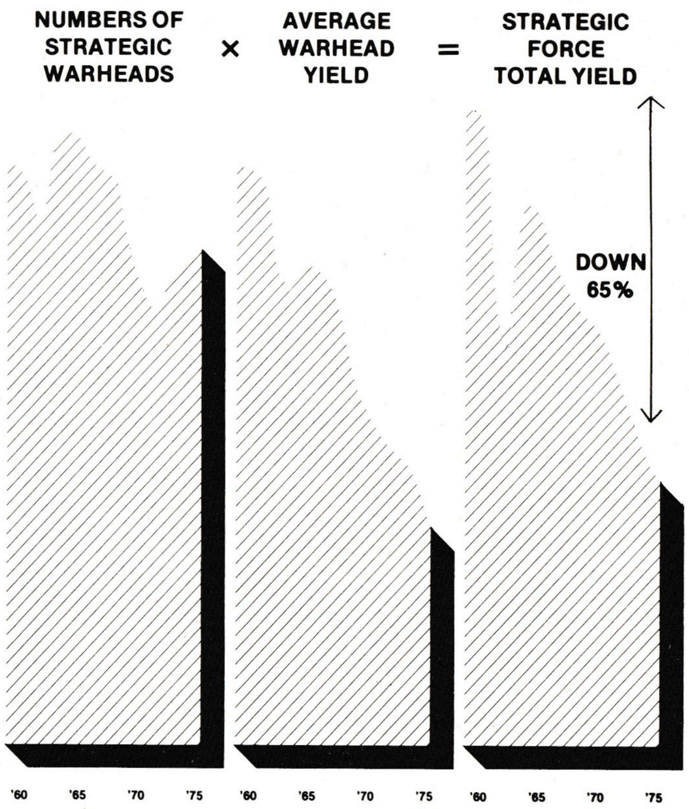


Fig. 3

(Source: "Foreign Policy", Nos. 15 and 16, 1974)

About A, B, D, and W programs

The office of nuclear explosives, headed by associate director Harry Reynolds, is responsible for the major portion of the Laboratory's weapons program. That office administers 62 percent of the weapons-funded work done here. The remainder of the weapons budget is administered by these programs and departments: testing, 21 percent; physics, 10 percent; chemistry, 4 percent; engineering research, 1.5 percent; and Z project, 1.2 percent.

Four separate programs, designated by the Lab as A, B, D and W, report to Dr. Reynolds and because of this their leaders were asked to join him in this roundtable.

A and B programs are complementary research organizations responsible for designing nuclear weapons. A-program people are the largest users of Lab computers, while B-program people perform many high-explosives experiments at Site 300, as well as extensive computer calculations.

The Evaluation and Planning (D) program is responsible for providing an understanding of issues central to national defense and thus to help determine nuclear R&D priorities. Major parts of D-program are the Military Requirements office which coordinates all LLL efforts in joint ERDA-DOD studies, Strategic and Tactical analysis groups which evaluate current and future nuclear weapon capabilities with respect to future military needs, and the Effects group which backs up all studies with calculational and experimental support to obtain a better understanding of nuclear weapon effects.

Weaponization (W) program is responsible for our interface with the ERDA production facilities. W-program activities include production process development, materials compatibility assessment, control and safety analysis, production and stockpile surveillance, and testing of weapons components and assemblies.

We've got a lot of exciting things to do ahead of us. Evidence of the spirit and morale is in the splendid performance of everyone connected with the accelerated test program which we just completed before the Threshold Test Ban went into effect. It was an effort which was amazingly successful. Our accomplishments outstripped the goals we had at the start of the effort.

WAGNER: Our morale has been affected by the disappointments and frustrations that come along with a declining budget that hindered our ability to do our job. But much of this is countered by the enthusiasm that comes from having solid, challenging technical problems to work on. Throughout our program I detect a sense of perserverance in our people that I think is just totally praiseworthy.

BARKER: Perserverance is one word you can use, but I prefer to say "dedication." People who are involved in the Nuclear Explosive Program at the Laboratory really have, I honesty believe, a moral commitment to the national defense. We know our job is important. We know we've got a lot that we can do.

NELSON: One thing that has helped morale tremendously in the last two years is getting two new Phase Threes (Ed. Note: for definition, see glossary) to work on. And the folks assigned to those are working nights and weekends; they are busy and enthusiastic about their jobs and they are in there digging and fighting to get the work done. Now two years ago we didn't have a single Phase Three in the Laboratory. I might add, however, that the Phase Threes are also responsible for our lack of resources with which to do advanced development work. As a result you have one group of people interested and enthusiastic but whose budget is coming out of the pockets of some of the folks who have advanced development things they would like to try, but can't. One of our goals is to increase the program size to a point where we can create a more sensible mix of projects so we can do all the things we ought to be doing.

REYNOLDS: Something else that I think adds a great deal of interest for our people is that the scientific and technological content of the weapons effort is extremely high. We are at the forefront of innumerable technologies—many technologies that exist only in the weapons laboratories.

LOKKE: I would say that all of us sitting here are very concerned about morale in the ways we've talked about: identifying what it is we are doing...how we fit into the country's purpose... identifying the exciting new technical things to look at...determining which are important...

NEWSLINE: This group represents the Lab's leadership in the weapons program. What are your goals for this program?

REYNOLDS: Well, there are several new Phase Threes coming along which we're going to actively campaign for. That's in the near future. The most urgent problem we have is getting back into the advanced development area which, as Bill pointed out earlier, we've had to essentially eliminate because of budget problems and the Threshold Treaty. There are a large number of new ideas in advanced development that are just waiting to be pursued and understood, and we're anxious to get at them.

NELSON: Speaking for my division, we have an expressed goal of modernizing the stockpile and putting it into a form that will maintain the effectiveness of the national defense over the next two or three decades. We have worked on specific plans oriented just towards that.

It might be good to mention here—I think a lot of people don't realize it—that we are responsible for certifying the reliability, safety and functionality of every one of our designed weapons that is in the stockpile throughout its life, until it is retired.

LOKKE: Getting back to the rest of our effort, we should mention that people in all of the programs represented here are participating in creating a long-range weapons plan. It's not just something that some of us are thinking about, but a plan people throughout the divisions are contributing to.

REYNOLDS: The plan considers a modernized stockpile, and the new technology and resources that will be needed to accomplish this. It also talks of the people, new buildings, facilities, instruments, equipment, and so on that we'll need in order to carry out the overall plan.

WAGNER: I have a little twist on this question. I think one of our goals is to put the scientific understanding of how nuclear explosives work on a much firmer basis—understanding in more detail the processes that go on in the explosives so that we can make more design advances as time goes on.

BARKER: Another goal to keep in mind is this: The fundamental purpose of the Laboratory is to understand the application of nuclear energy to military purposes. Times will change, technology will advance—not only for us but for the Soviet Union. So we have to maintain our scientific efforts, and at the same time maintain a communication path with the military services and the DOD. We have to make sure that the country will have the options available to take advantage of those combinations of military technology and nuclear explosives technology which can do the defense job of the U.S. at the cheapest possible cost.

What I'm saying is, we can't forget the military context of our scientific research.

NEWSLINE: Does anyone have anything he would like to add?

REYNOLDS: Maybe one final point. We all are really optimistic about the future—about our ability to contribute to the nation's defense and about the likelihood of improvements in our resources to do that work.

NEWSLINE: Thank you, gentlemen.

Strategic weapons top Lab accomplishments
Emphasis shifting to tactical systems

When U.S. and Soviet negotiators sat down at Geneva in 1969 for the first round of the Strategic Arms Limitations Talks (SALT I) their immediate concern was one of the definitions.

Would strategic weapons be defined, as the U.S. insisted they should, as those of intercontinental range capable of destroying each nation's industrial and military ability to wage war?

Or would the definition, as the Soviets wanted, not concern itself with the distance a weapon can travel but only its ability to hit the other side?

The Soviets pushed their definition out of concern over the United States' so-called Forward Based Systems, nuclear weapons and aircraft which are deployed in Europe and other nations for the defense of U.S. allies. From their European bases, these limited-range weapons have the capability for hitting points inside the Soviet Union.

But the U.S. adamantly opposed the Soviet view since these limited-range tactical nuclear weapons, primarily designed for close-in combat support and not long-range strategic strikes, are an essential part of the American defense of Europe. Faced with a larger Soviet bloc force in terms of manpower and equipment, NATO countries rely on these weapons as a deterrent to invasion.

The dispute eventually was settled in favor of the United States' position: SALT negotiators would focus on long-range bombers, intercontinental ballistic missiles (ICBMs) and submarine-launched ballistic missiles (SLBMs). For the United States that meant its B-52 bombers, the Minuteman and Titan ICBMs, and the Polaris and Poseidon SLBMs—its primary deterrent to war.

"Generally the debate over whether weapons are strategic or tactical has focused on the delivery system and not on the nuclear device," noted Marv Gustavson, the Laboratory's assistant associate director for military systems.

"In terms of nuclear explosives R&D the distinction isn't very useful. The technology is basically the same, regardless of whether the explosive is going to be used for strategic or tactical purposes."

That's not to say, noted Gustavson, that there aren't some technical differences. Generally strategic warheads or bombs tend to be more powerful. And frequently designers face different challenges depending on whether a particular nuclear device is intended for a tactical or strategic system.

Tactical nuclear explosives, for instance, may need to be more compact in order to fit a smaller delivery system. In fact, the smallest nuclear weapon in the U.S. arsenal is the 6-inch artillery shell for the Army's nuclear cannon.

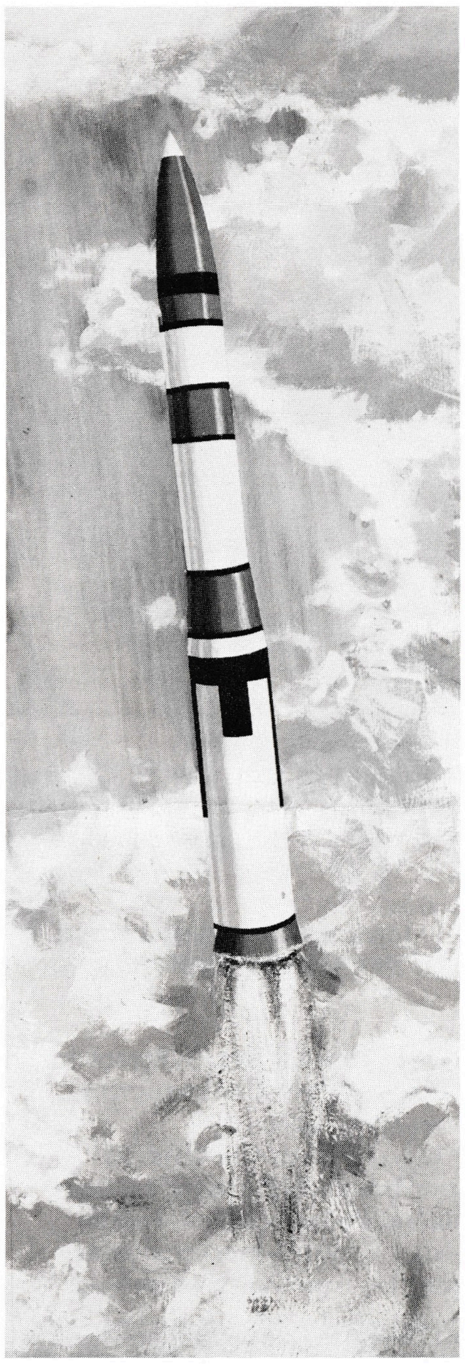
The design of that artillery shell was one of several contributions the Laboratory has made in the tactical weapons arena. But the biggest contributions by the Lab to the nation's defense have been in the area of strategic weapons.

Overshadowing the actual design of the warheads has been the Lab's successful effort to miniaturize thermonuclear warheads, an advance that many credit with leading to development of SLBMs.

Noted Jack Rosengren, project physicist for the first Polaris warhead design, in a 1972 issue of *Newsline:*

"High-yield warheads were simply too large and heavy to be thrown any real distance by any U.S. missile that would fit on a submarine. It was expected that it would take years to develop a large, liquid-fueled missile that could carry a megaton-class warhead the 1,500 miles that the planners considered necessary."

However, Lab designers came up with a method for significantly cutting the warhead size and weight. That advance enabled the Navy to use a much smaller, solid-fueled missile on its submarines. And so, in 1960, the first fleet of Polaris Al missiles carrying Laboratory-designed warheads took to sea.



Designers, however, didn't stop there. Further refinements in miniaturization technology made it possible for the U.S. to replace a single warhead on a missile with several, smaller-yield warheads.

This was the so-called Multiple Reentry Vehicle, a development that saw its first applications in the second-generation Polaris missiles. In the late 1960s the U.S. began replacing the single warhead on some of its Polaris Als with three warheads.

Next Lab designers came up with warheads for the Multiple Independently Targetable Reentry Vehicle (MIRV) that allows a missile to carry several warheads, each of which can be directed at separate targets.

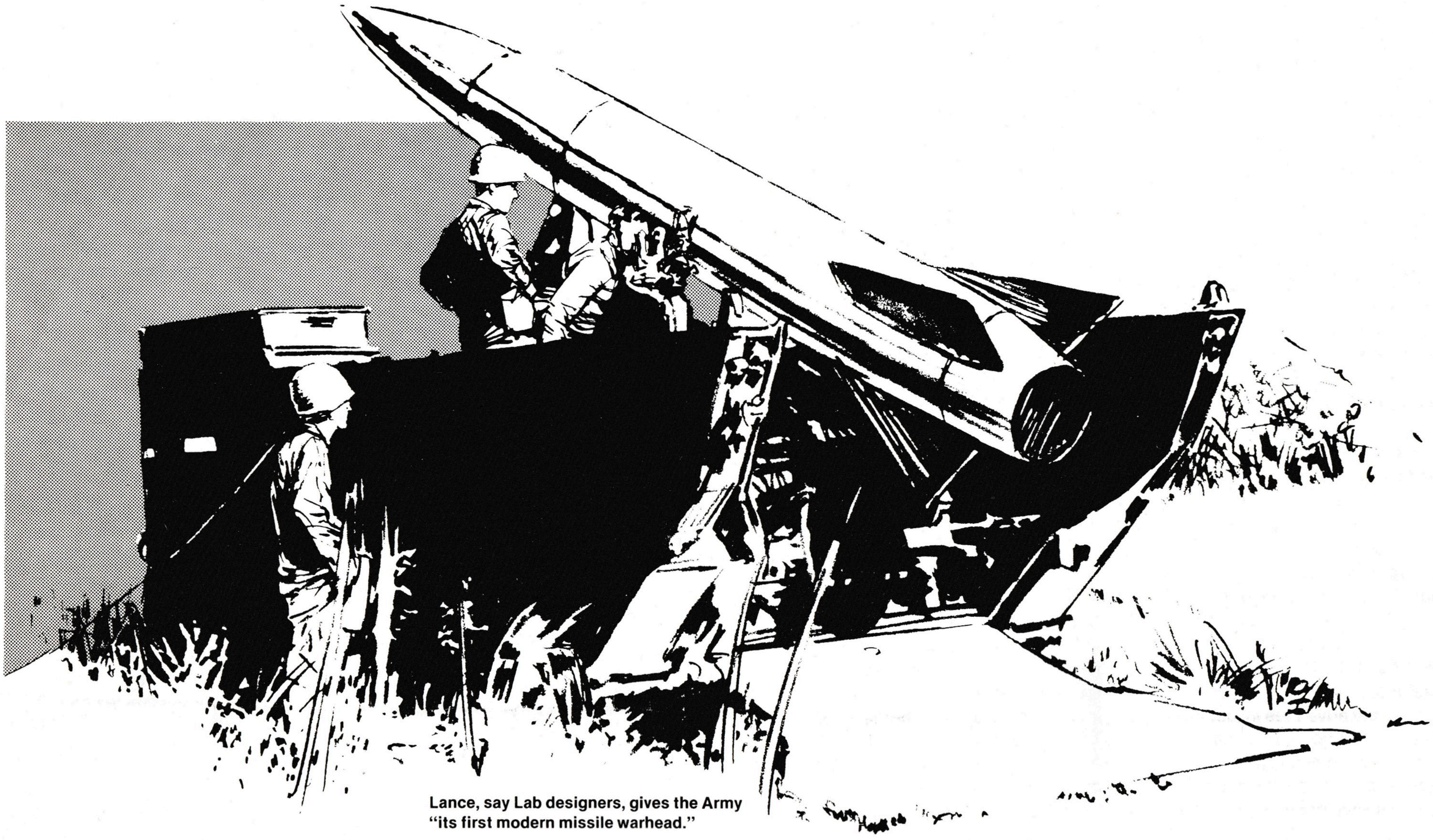
In 1970, the U.S. began phasing out some of its Polaris missiles and replacing them with the Poseidon, a MIRVed version of the first SLBM. The Poseidon warhead, like those for the previous SLBMs, was designed by the Lab.

"At the inception of SLBMs it was a major challenge for us to provide even a single warhead per missile of practical size," said Marv Gustavson. "Now some of our submarine-carried strategic missiles can hold up to 14 reentry vehicles."

But, noted Gustavson, the payoff from efforts by designers to make warheads smaller wasn't limited to just the SLBMs. The Lab also was chosen to apply its expertise to the country's Minuteman ICBMs, a solid-fueled missile developed to replace the aging Atlas.

In 1970, MIRVed Minutemen began taking their place beside their older brethren. The Lab, in fact, was repeating the same type of development history it had achieved with the Polaris.

Lab designers are currently trying to push MIRVing technology a step farther with development of a warhead for the MARV, or Maneuverable Reentry Vehicle. MARV will be able to avoid defensive missiles fired at it by changing its direction in flight. That, say designers, will give the U.S.



Lance, say Lab designers, gives the Army "its first modern missile warhead."

strategic forces a deployment option which is now missing.

In concentrating on the U.S. missile forces, Lab designers have played a minor development role in bombs for strategic aircraft. Today, however, designers here are at work on a bomb for the proposed B-1 and other aircraft.

Historically, the Lab's emphasis on strategic systems has also limited its role in development of tactical nuclear weapons; most have been developed by Los Alamos. But in recent years the Lab has been getting more involved in work on tactical weapons. And that, in part, is due to what some see as approaching parity between strategic forces of the U.S. and Soviet Union, as well as disparity between the two countries' conventional military forces.

"If the Soviets attacked Europe and we didn't have tactical nuclear weapons, we'd be completely inflexible," says Chuck Gilbert, deputy director of ERDA's Division of Military Application.

"Tactical weapons, however, give us the option to use nuclear explosives to selectively respond to an attack by their conventional forces or tactical nuclear forces. Besides, a tactical nuclear weapons force in Europe is a strong deterrent to an invasion by Soviet bloc nations."

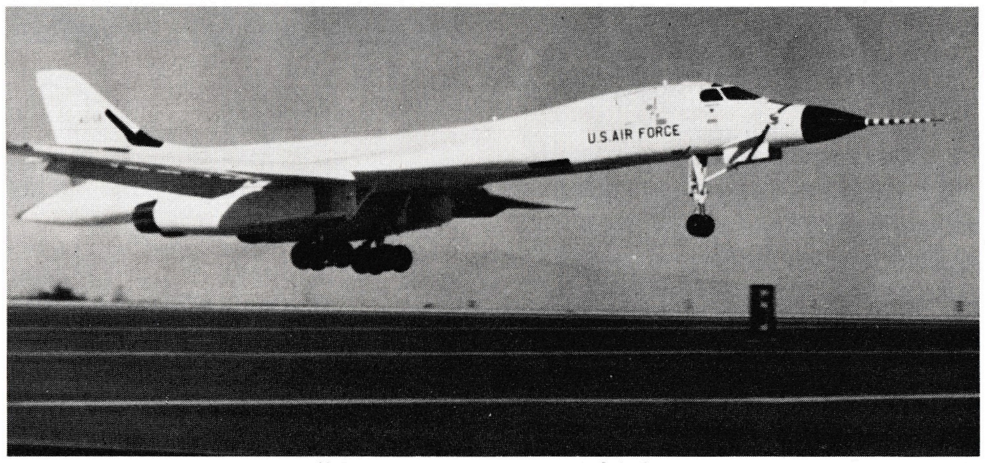
One of the Lab's most recent contributions to the nation's tactical nuclear arsenal is the warhead for Lance, a surface-to-surface missile that a few years ago was deployed to augment the NATO forces.

The Lance warhead, however, isn't the first tactical missile warhead the Lab has designed. Researchers here also developed the warhead for the Navy's SUBROC, a tactical rocket which can be launched from a submarine like a torpedo. Once launched, SUBROC emerges from the water to hit a distant surface ship. It can also reenter to hit a submerged submarine which is too far away to be reached by a conventional torpedo.

Currently Lab designers are developing a new artillery shell for the Army's 8-inch nuclear cannon. That shell, says ERDA's Edward Giller, "will be the first U.S. weapon specially designed to reduce collateral damage from blast and radioactivity."

Notes Marv Gustavson in summary: "Gross destruction is really not the name of the game. Right now it is clear that the Soviets have the capability to destroy Europe. But their goal may be to win Europe. And our goal is to be able to defend Europe without destroying it.

"So what we are trying to develop are tactical weapons that can stop an attack, terminate a war, and still protect Europe. It is a very formidable problem. Achieving that goal will provide a further deterrent to aggression."



Laboratory designers currently are working on a high-yield bomb for the B-1 (above) and other aircraft. It incorporates advanced safety features to prevent fissile material from scattering in the event of a crash.

The job is far from finished

"When you realize the wealth of developments that are possible in the nuclear arena, it is hard to foresee an end to our work."

The nation's nuclear weapons program has made dramatic strides since that fateful summer morning in 1945 when the New Mexico desert reverberated from the shock of Trinity, the world's first nuclear test.

Today, after more than 30 years of probing the military potential of the atom, scientists have given the nation an awesome capability:

- *Weapons whose destructive force can be measured in millions of tons of TNT instead of thousands.*
- *Warheads so light and small that several can be thrown by a land or sea-based missile thousands of miles to an enemy target.*
- *Weapons which are capable of destroying an enemy's attacking missile forces.*

In fact, the disparity between today's weapons and those of the late 40s and 50s is as great as that between the jumbo jet and the Wright brothers' first airplane.

With so many advances in just three decades, could it be that nuclear weapons technology has about reached the end of its line, that no more real improvements are in sight?

Some people, even those formerly associated with the nation's nuclear weapons program, say yes—that nuclear weapons R&D is on a plateau.

But to others that assessment brings to mind the story of the patent official who quit his job a century ago certain there would never be future patents. History gives clear evidence of his error in judgment, they point out.

One of those in the latter group is Marv Gustavson, the Laboratory's assistant associate director for military systems, who draws a comparison between the fields of nuclear energy and air transport.

"We've heard people say many times that the ultimate has been achieved in the air transport business," says Gustavson. "First it was achieved when man was able to fly across the ocean, then it was achieved with the first metal airplane, then came the jet engine.

"It seems that in each successive decade or so we've seen a major innovation, a major change, an addition to our capabilities. And nuclear explosive technology is just like that. When you realize the wealth of developments that are possible in the nuclear arena, it is hard to foresee an end to our work."

For Gustavson and other weapons scientists, the overriding objective of that work is to provide the nation with a strong nuclear deterrent. But, they caution, deterrence isn't guaranteed by the mere existence of nuclear weapons.

If the U.S. weapons force is vulnerable to attack, they say, there is no deterrence. Likewise, there is no deterrence if the use of the weapons could destroy the very nation the U.S. is trying to defend; in such a case, an adversary could easily believe the weapons would never be used.

As a result, weapons scientists are attempting to increase what they term the "survivability" of nuclear weapons, and reduce unwanted damage.

At the same time their research efforts are aimed at providing new capabilities which will give greater flexibility to military strategists, increasing the safety and security of weapons, and reducing the cost of building and maintaining a nuclear arsenal.

A look now at some of the goals of current research efforts.

Safety—The prevention of accidental detonations, as well as reductions of hazards associated with transport, storage, and handling of nuclear weapons has long been one of the forces driving the R&D program. But that effort took on new meaning in the 1960s with two accidents involving nuclear weapons.

On January 17, 1966 a B-52 bomber collided with an air tanker over Palomares, Spain, dumping four hydrogen bombs into the Atlantic and onto the land. Some radioactive material was dispersed during that incident. Safety mechanisms guaranteed that no nuclear detonation occurred.

Two years later a nuclear weapons-laden B-52 crashed at Thule Air Force Base in Greenland, resulting in the dispersal of some plutonium.

Edward Giller (left) with an associate.

"Thule and Palomares showed us that accidents could happen," says Edward Giller, ERDA's deputy assistant administrator for national security, "and as a result the safety considerations became even more intense. We began to worry more about what would happen if these weapons were treated unkindly."

Researchers stepped up attempts to develop new safety mechanisms and to package a weapon's nuclear material in such a way that there would be no radioactive dispersal should there be another Thule or Palomares.

Security—Closely akin to safety, weapons scientists say, is the need to provide security for nuclear weapons so they can never be used by an overzealous friend, or by a foe.

History, they argue, has proven peacetime security efforts to be more than adequate. But like safety considerations, that effort has taken on a new emphasis in recent years. The reason is worldwide terrorist activities.

Weapons designers, in fact, have come up with a tamperproof device which guarantees that weapons won't work in the event they should fall into the the wrong hands (see story p. 11).

"The Laboratory was one of the earliest groups to work on the control of nuclear weapons," says Marv Gustavson. "Many of the innovations which are now finding their way into the stockpile had their inception in the work done here. But we don't want to stop there."

Equally as important as security in peace is security in war, and that brings into play the concepts of "survivability" and "vulnerability" of nuclear weapons.

Survivability requires that no enemy could logically conclude that he could knock out the entire U.S. strategic arsenal with a first strike; that there would be weapons left to deliver a retaliatory attack. One way to assure that is to "harden" missile silos so the weapons can't be destroyed. Another is to make U.S. strategic forces more mobile. That, for example, has been achieved with submarine launched ballistic missiles such as the Polaris and Poseidon, for which the Lab developed the warheads.

The necessity of having weapons that can survive an enemy's first strike has been underscored by Secretary of Defense Donald Rumsfeld. He has said that U.S. strategic forces must have the capability "to strike back with devastating force at an enemy's economic and political assets."

Rumsfeld went on to say, "Such a force is essential not only as the basic deterrent, but also as a capability that can be withheld so as to deter any attack on the U.S. and its allies' cities and population."

The concept of vulnerability, on the other hand, deals with the possibility of a nuclear warhead being destroyed by an enemy's defenses before it reaches its target.

Bob Squire, formerly a staff man in the Nuclear Explosives Office and until recently a member of D-Division, notes that vulnerable deterrent forces would be fundamentally destabilizing.

Making warheads less vulnerable involves devising ways to harden them against nuclear effects, including x-rays, neutrons and electromagnetic radiation. But the problem of vulnerability has also been addressed by development of a new class of weapons, explains D-Division Leader Bob Barker, citing the Lab's development of MIRV warhead technology.

"In the 60s the country became concerned about Soviet ABM developments," Barker says. "If a reentry vehicle could be shot down out of the sky we wouldn't have a deterrent.

"So the U.S. answer was MIRVing, going to multiple independently targetable warheads on a single ICBM. If we could throw many objects at them they couldn't possibly hit them all simultaneously. They would know that a sufficient number would get through to cause unacceptable damage, and deterrence would be maintained."

Collateral Damage—Maintenance of an effective tactical nuclear deterrent, note ERDA officials, is the key reason why the nation's design laboratories are embarked on a major program to reduce collateral, or unwanted, damage that may occur from use of nuclear weapons. These tactical weapons, says Chuck Gilbert, a 16-year Laboratory veteran and currently deputy director at ERDA's Division of Military Application, are primarily designed to stop an enemy attack. As such, they may be called into battle in a region where U.S. troops or allies are located. Gilbert's boss, DMA Director Major General Joseph Bratton notes that because of this the reduction of collateral damage is a very important consideration to the United States' densely populated European allies.

"Because our strategy in Europe is a defensive one, one must presume that if there is a tactical nuclear war at least a good part of it would take place on friendly soil," says Bratton, an Army general who served as executive officer at NATO headquarters before being assigned to ERDA.

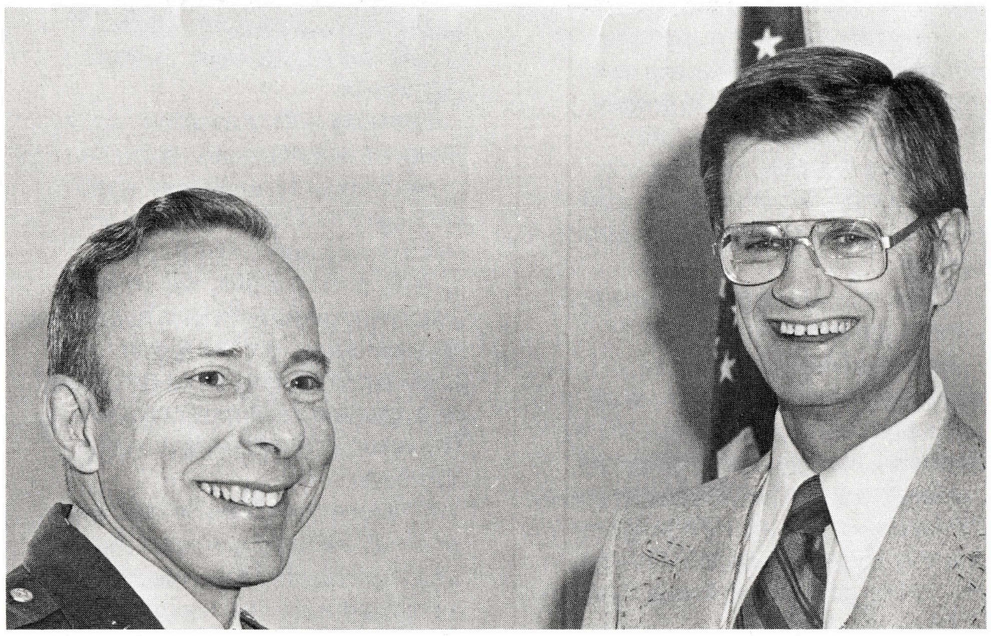
"The European nations on whose territory such a war might be fought are extremely conscious of this collateral damage factor. So it is politically and militarily an important problem that we are attempting to solve."

Gilbert also notes that the deterrence value of tactical nuclear weapons could be nullified if an adversary feels the United States would be reluctant to use them.

"Therefore," says Gilbert, "what we are aiming for is tactical weapons that would have the capability to knock out a group of tanks or a bridge without spreading radiation all over the countryside.

"That way our adversaries would know that we would be less hesitant to use tactical nuclear weapons, and they would have to think twice about starting any conflict."

Stockpile Modernization—The country's nuclear weapons are growing old. Many have been in the stockpile since the 60s. People in the weapons program say that it will tax the development capabilities of both Livermore and Los Alamos to provide replacements and new designs.


General Bratton and Chuck Gilbert

Nuclear weapons have a finite life. As a result, there comes a time when they must be replaced, modernized, or retired.

Says Joseph Bratton: "When our weapons become obsolete that gives us the opportunity to replace them with better weapons. And by that I mean cleaner weapons; smaller, more precise weapons; weapons that are more efficient today in terms of reliability and lifetime; weapons that require less maintenance; safer, more secure weapons."

But, note Bratton and Gilbert, most nuclear weapons are retired not because they have grown old, but because their delivery systems are obsolete.

Changes in offensive or defensive strategies may render an older airplane or missile ineffective. So new delivery systems must be built, and that means weapons designers must come up with warheads which are tailored to the needs of the new system.

Weapons scientists at Livermore, for example, are currently involved in development of a bomb for the B-1, a new strategic bomber. This bomb will also be carried on many other aircraft, and will allow the retirement of several older bombs.

Weapons Costs—Deterrence in the nuclear age is expensive, scientists readily admit. But, they point out, an active research and development program can substantially reduce overall costs.

One way is through development of maintenance technologies which will require much less manpower to make certain that stockpiled weapons are operational.

Another is by the development of lighter, but higher yield, warheads. This means the Department of Defense can use smaller, and cheaper delivery systems.

Says Marv Gustavson: "It may be obvious, but it is seldom noted, that the size of the nuclear explosive package to be delivered sets the minimum size required for the delivery vehicle."

Weapons scientists also note that development of new concepts can give the nation a strong nuclear deterrent without the need for building additional missiles. As an example, they point to the successful effort by the U.S. design laboratories in the 60s to miniaturize thermonuclear weapons, an effort that led to the ability to MIRV U.S. missiles.

Without the MIRVing capability, they say, the U.S. might have had to build additional missiles to counter what was seen as a threat from Soviet development of an ABM. And they estimate the cost of those additional missiles and their 10-year operation at $20 to $30 billion. The total bill for *all* nuclear weapons research and development during that period amounted to a few billion dollars, they say.

ERDA's Edward Giller, noting that nuclear warhead costs represent on the average only about 10 percent of the cost of a weapons system, says in summary:

"It is clear to all of us that designers of the warhead are part of an armament team that is made up basically of Department of Defense people building a carrier and ERDA providing the warhead.

"And we have found that by pushing the state of the art on warhead designs, we can allow the defense people to ease up on requirements for the carrier system—the missile, the airplane, or submarine—where the big dollars really are."

One aspect of the R&D program that is likely to never end, researchers say, is the sheer necessity of increasing the nation's inventory of knowledge about how nuclear weapons work and their effects.

Obviously thermonuclear weapons

work; they've been tested many times. But weapons researchers say the field is so young and vast that there may be technological possibilities not yet uncovered.

Finding out what is possible, they note, pays dividends in two, sometimes interlocking, ways: by providing the nation with new options for upgrading its defense capabilities and by giving it clues as to avenues of research its adversaries might be pursuing.

Underscoring that last point is a 1974 briefing document prepared for Harry Reynolds, the Lab's associate director for nuclear explosives.

Very early in the development of a U.S. military system, the document points out, public argument over the need for funds will bring out some details of the system's performance. That information is frequently published and thus made available to the Soviet Union.

In contrast, the document notes, the Soviet Union is such a closed society that U.S. intelligence of Soviet military systems doesn't really begin until the Russians test their new weapons.

It is that difference between the U.S. and the Soviet Union, weapons scientists feel, that makes it necessary for the U.S. to maintain an active R&D program as a hedge against surprise.

Some people, however, are concerned that the aggressive exploration program being pursued by the Soviet Union may have already charted new paths and uncovered new options which are not known to U.S. weapons designers.

"Certainly in the past it was half-way reasonable to say that we knew everything that they might have found out," Gustavson says. "But that may no longer be true. If we presume that they only operate in the same arena that we know, then we are liable to be very much surprised.

"In fact, I am personally becoming more and more worried that there may be many things that we don't yet know about because of the real dollar limitations on exploration in a field in which there seem to be more things to explore with every passing year."

Combating the terrorist threat

Wayne Beech, former assistant director for research and development at ERDA's Division of Military Application, calls it a "changing, dynamic threat."

Beech's observation, although applicable, is not directed at the military posture of other nations. Instead, it is aimed at worldwide terrorist activities and the possibility, however remote, that one day terrorists might attempt to get their hands on a nuclear weapon.

"With organized terrorist activities it becomes increasingly important that nuclear weapons be extremely secure," says Beech, echoing a sentiment shared by others in the nuclear weapons R&D community.

Standard security provides one way of keeping U.S.-made nuclear weapons out of the hands of terrorists: surround the weapons with fences and security patrols, and develop sophisticated perimeter devices to detect and ward off intruders.

But there is a more novel way which the nation's nuclear weapons laboratories have spent a lot of years and effort trying to develop: nuclear weapons that simply won't work if stolen.

The key to that approach is something called a command and control system, a bit of electronic wizardry that can be built into a nuclear weapon to keep the weapon's awesome power in check.

Although the comparison is highly deceptive, the system operates like a lock on a safe; without the proper combination the safe can't be opened. Likewise, without the proper code a nuclear weapon equipped with a command and control system can't be detonated.

Marv Gustavson

According to Marv Gustavson, assistant associate director for military systems, the command and control device which has been developed rests on one basic principle: that the United States would rather "destroy" a nuclear weapon than have it used without proper authorization.

By that Gustavson means that any attempt to use the weapon without the proper access code will result in it becoming essentially a useless dud. "The trick," said Gustavson, "is to do that in a totally non-violent way so that nobody near the weapon will be hurt."

Nuclear weapons designers at Livermore began turning their attention to such a security system in the 1960s, a time when the nation's nuclear arsenal began to grow substantially.

Says Edward Giller, ERDA's deputy assistant administrator for national security:

"The command and control aspect of nuclear weapons became more and more important in the 1960s. We didn't want these things to get loose. We had to put some controls on them."

To nuclear designers that challenge seemed to rest with the nuclear weapon itself, rather than with perimeter control measures.

"Perimeter controls are a highly effective technique for safeguarding nuclear weapons," says Gustavson. "But if you think of the control process as a chain, then clearly the thing you want to do is to forge a very good link for the chain at the nuclear weapon itself.

"So we set to work devising a system for the weapon which is so good in itself that perimeter controls would be just a part of that chain, and not the key link. And what we know how to do today makes that entirely feasible."

Some say such a system could solve what is an apparent dilemma facing people concerned about strategies for protecting nuclear weapons in both war and peacetime.

In peacetime, for example, the aim of security measures is to guarantee that weapons cannot be used by unauthorized people. In war, however, the central objective is to make certain that an enemy cannot destroy our stockpile.

"Frequently security strategies for protecting weapons in peace and war tend to fight one another," says D-Division Leader Bob Barker.

"To protect against a terrorist you would like to have all your weapons in one place where you can put up a fence and ring it with guards," he says. "But in war you want to disperse your weapons as much as possible so the enemy can't destroy them with one attack.

"We believe that advances in command and control technology might permit more widespread dispersion of our weapons in peace, which would be more compatible with the situation one would like to have in the event of war."

Arms control: The people

Advisors' role takes Lab scientists around the globe

The little sign near his desk labels Harry Reynolds' office as "Detente Weapons Systems, Inc."

The words capture not only the ambivalence of the world's current political situation, but the dual nature of the Lab's role. For, just as—in fact, because—the nation must turn to either Livermore or Los Alamos for new kinds of nuclear warheads, so it must turn here for technical expertise when the goal is arms control.

The control of arms—the attempt to maintain the stability of the deterrent and minimize potential destruction while maintaining a capable military force—is an integral concern of the weapons program from the start.

The following is a report on Laboratory people who participate in arms control talks and the variety of talks they have been involved in.

At any time, Lab people are likely to be in Moscow, Vienna, Geneva, New York or Washington consulting on arms control matters and serving on American delegations at various talks.

For the last couple of years SALT II talks have been taking place on-and-off in Geneva. Until this spring a key member of the U.S. delegation was Dr. Michael May, now an associate director-at-large and formerly the Director of the Lab. According to Robert Duff, the ERDA arms control chief, May "had a sort of a senior statesman role in the whole arms control equation."

May attended SALT II as the representative of the Secretary of Defense. On Dec. 18 he was awarded the DOD's highest civilian medal for his "outstanding intellectual acumen, consummate negotiating skill, and sound judgment" displayed at SALT. The award credited May with earning "the profound respect of his U.S. colleagues and Soviet counterparts."

Recently concluded were U.S.—U.S.S.R. talks on peaceful nuclear explosives (PNEs), a companion issue to the Threshold Test Ban Treaty (TTBT).

Through all five sessions of the PNE negotiations in Moscow (which started in 1974), the Lab's Warren Heckrotte was present. Milo Nordyke was also there for most.

Their role, said Duff, was "to bridge the gap betweeen the technical and the policy and international political implications of arms control.

"But it was a little more than just providing technical information," Duff continued.

"Warren Heckrotte, because of his 10 years of experience in arms control, kind of knows the policy side. He is a recognized authority not only by people in ERDA, but by people in the whole interagency involvement, including the State Department, DOD, Arms Control and Disarmament Agency, and National Secuity Council."

An indication of the esteem in which Nordyke is held at ERDA came last year when his presence was desired at a UN meeting; he could not attend because he was at the Moscow talks.

"Sometimes they get spread pretty thin," said Duff.

The UN occasion was the semi-annual Conference of the Committee on Disarmament (CCD) in Geneva. The UN had directed the committee to give special attention to the arms control implications of PNEs.

Besides Heckrotte and Nordyke, Lab people who have assisted on various CCD meetings include Bill Grayson, Larry Germain, Joe Landauer, Pete Moulthrop, Fred Holzer and Lyn Ballou.

Another forum for discussion of PNEs is the International Atomic Energy Agency (IAEA). The ultimate goal of the IAEA is to share PNE technology among the various nations. Duff said the Lab is now involved in IAEA studies on the health and safety, economic and legal aspects of PNEs.

Over at the Pentagon, Mike May is not the only Lab person who has worked on arms control. Joe Landauer, most recently deputy leader of A-Division and for 18 years a scientist and staff man in weapons work here, went there for a two-year stay in the fall of 1974.

Under the Intergovernmental Exchange Act, Dr. Landauer received his paycheck from the Lab while working in the Policy, Plans and National Security Council Affairs section of the International Security Affairs (ISA) division of the Office of the Secretary of Defense.

Specifically, he served as an advisor on the TTBT and on non-proliferation concerns. He worked under Jim Wade, a former military research associate at the Lab, in the same office through which Michael May worked.

Among other things, Landauer served on what is called a "backstopping" committee. That interdepartmental group provides input to the Washington policy-making process and communication to American delegations, most specifically recently the TTBT one in Moscow that included Heckrotte and Nordyke.

Landauer wrote a Pentagon position paper on non-proliferation that was delivered before the Senate arms control committee last October by Robert Ellsworth, then assistant secretary of defense for ISA.

The paper stressed that the DOD opposes weapons proliferation anywhere in the world.

"There can be no net security advantages to the U.S. from proliferation by any country," it said.

It argued that, "U.S. efforts to assure that its non-nuclear allies and friends do not perceive themselves threatened can have a large role in persuading these countries not to develop their own nuclear weapon capability."

In general the involvement of Lab people in arms control matters such as these has increased dramatically in the past several years because of developments such as the nuclear explosion by India and TTBT.

That involvement has an impact back at the Lab. Said Duff, "There is an exchange that takes place particularly after Lab people work with me here in Washington.

"They attend interagency meetings where positions are developed, and they begin to have real understanding of policy machinery. Then they feed back into the Lab. Harry Reynolds and others have stressed to us their interest in having your fellows participate," Duff told *Newsline*.

Moscow Memories

In Moscow to talk about nuclear explosives, Ed Fleming was awakened on the night of November 5, 1974 by "an enormous roar" outside his hotel window.

"I got up to look," (as you would even if you weren't in Moscow thinking about nuclear explosives) "and there were what seemed like hundreds of tanks just running down the street."

He was not dreaming.

A Lab veteran then on leave to the Atomic Energy Commission, Fleming (now on the Directors staff) was on the U.S. delegation to the first round of U.S.—U.S.S.R. talks on peaceful nuclear explosives.

The delegation found the work extremely demanding, the more so because of ground rules which forbad taking a tape recorder or secretary into the negotiating sessions.

It was known that the Soviets chose their words very carefully and that sometimes the full meaning of those words became clear only under microscopic examination.

"So there we were, everyone of us along this table, just writing furiously as their interpreter is going on," Fleming said. "Then you go back to the embassy, and you write down everything they said word for word. You compare notes and say, 'Exactly what did he say?' and, 'What was that word again?'

"When the reconstruction of the Soviet statements was completed," Fleming said, "we would all sit around and try to figure out what it meant."

Then the verbatim statements were sent to Washington daily to a backstopping committee, along with other pieces of information. (In this latter category fit Fleming's report one day that a man from the U.S.S.R. foreign ministry told him the night before that the ministry's leadership had been sold on the need for a Soviet PNE program. "He knew doggone well I would report what he told me," Fleming said. "That's part of the game.")

With it all, the delegation often didn't leave the embassy until after 10 p.m. to go to dinner. Work usually began again at 8:30 a.m.

But it wasn't all work. Weekends were generally free, and the Americans were treated with some appreciation for their bourgeois tastes.

"They really went out of their way to treat us very, very well," Fleming said. "Each night we had dinner on the top floor of the Rossiya, which is very difficult to get into. It's a very nice restaurant with an American-style combo and they gave us the best food they had." (Fleming rates that food as "not bad," with some exceptions.)

Most of the costs for food, lodging, transportation and entertainment were borne by the Soviets.

The Americans were treated, among other things, to the Bolshoi Ballet and the Moscow circuses, as well as to tours outside Moscow.

"I bet I saw every icon in Russia," Fleming said, "but it was fascinating."

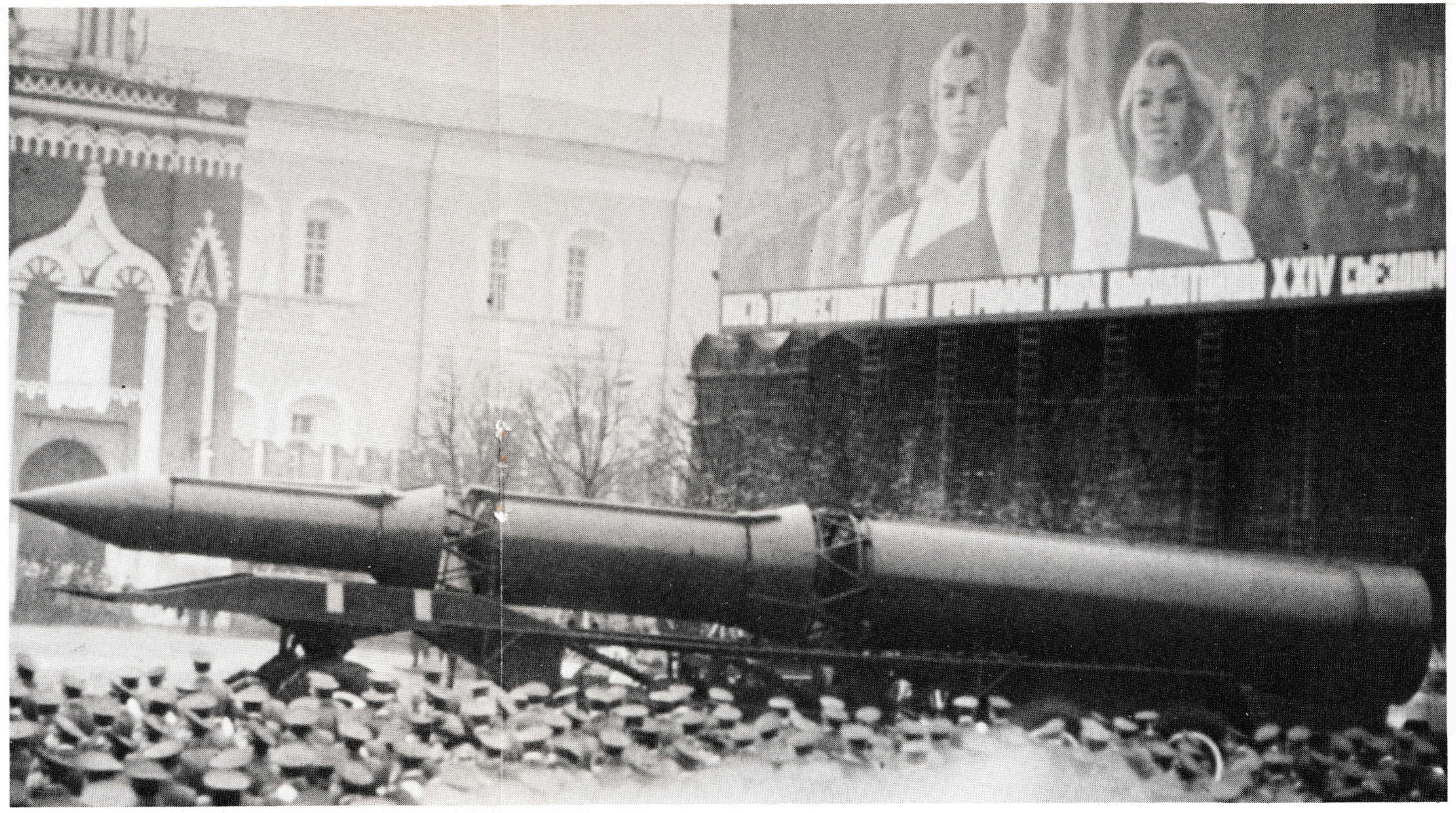
The most fascinating sight, though, began with those tanks rolling down the Moscow streets in the middle of the night.

The Russians were preparing for their annual October Revolution parade (now held in November because of a change in the Russian calendar). In that event the Soviets parade their weapons in front of massive throngs of people lining the streets of Red Square. It is an event intelligence people throughout the world watch with some interest.

The Americans were awarded tickets, which was considered quite an honor.

"There was everything from ICBMs, to tanks, to...the whole works," Fleming said. "They show it all, and some of the pieces are absolutely huge.

"It was awfully impressive," he said, "and a sight not too many Americans are privileged to see."



Ed Fleming wasn't about to allow his Moscow experience slip by without making some personal record of it. He took the top and bottom photos at the October Revolution parade, at which the Soviets march their weapons down Red Square before throngs of spectators. Top photo is an ICBM. At right is a shot of the Moscow skyline Fleming took from his hotel. The center photo shows the American and Soviet delegations facing each other. Fleming is looking at camera, and Warren Heckrotte is second from right.

Arms control: The issues

Moscow testing talks end, but SALT discussions continue

The U.S. and U.S.S.R. have been thrashing out arms control issues in two major forums. From most perspectives, the most important has been SALT—the Strategic Arms Limitations Talks.

For the Lab, however, more relevant were the recently concluded Moscow talks on PNEs—peaceful nuclear explosives. They were seen as an adjunct to earlier talks on a TTBT—Threshold Test Ban Treaty.

Because SALT has—until now, at least—mainly been concerned with launcher numbers, it has had less direct impact on the Lab than the proposed TTBT, even though the latter has yet to be ratified. Once a weapon system has been developed, the question of how many copies are produced has little impact on the Lab.

A test ban, on the other hand, affects the very nature of the Lab's work.

Livermore's first experience with test bans came in the late 1950s, when the U.S. and Russia placed a moratorium on all testing. As the moratorium approached, the Lab embarked on a highly accelerated testing schedule, the pressures, upheavals and excitement of which are legendary among weapons program veterans.

Although the moratorium was open-ended, U.S. policy was to treat it as if it were permanent. When the Soviets finally broke the moratorium after three years, the Laboratory was not prepared for any significant new tests. After several months of preparation, however, a much needed schedule of testing was begun.

Then, in 1963, came the Limited Test Ban Treaty, which put an end to atmospheric testing, thus forcing the Lab's testing underground.

Then, in 1974, President Nixon and Soviet leader Brezhnev signed an agreement to limit all nuclear weapons tests to 150 kilotons after March 31, 1976. That's the equivalent of 150,000 tons of TNT, more than seven times the size of the Hiroshima bomb, but only a fraction the size of some that have been tested.

After the agreement, once again in anticipation of a deadline, the Lab launched an accelerated testing program, though to a lesser degree than in 1958.

Meanwhile, the two nations were talking about the problem of PNEs, known at the Lab as Plowshare.

Although the U.S. has largely discontinued Plowshare, the Soviets have an active program aimed at the eventual excavation of canals, diversion of a river, and recovery and storage of ores and fossil fuels.

The Soviets were unwilling to allow PNEs to be covered under the TTBT because some PNE efforts require more explosive power than 150 kilotons. The Americans, on the other hand, were unwilling to simply exclude PNEs from coverage because of the fear that the Soviets might test weapons under the guise of PNEs.

This was the dilemma that required 93 negotiating sessions in Moscow over 19 months. The main features of the resulting 23-page accord finally reached in April are two:

- The limit for individual PNEs is kept at 150 kilotons, but more than one explosion will be allowed at each PNE occasion.
- The treaty will be monitored by the presence of scientists and equipment from the other nation at any PNE event exceeding agreed levels.

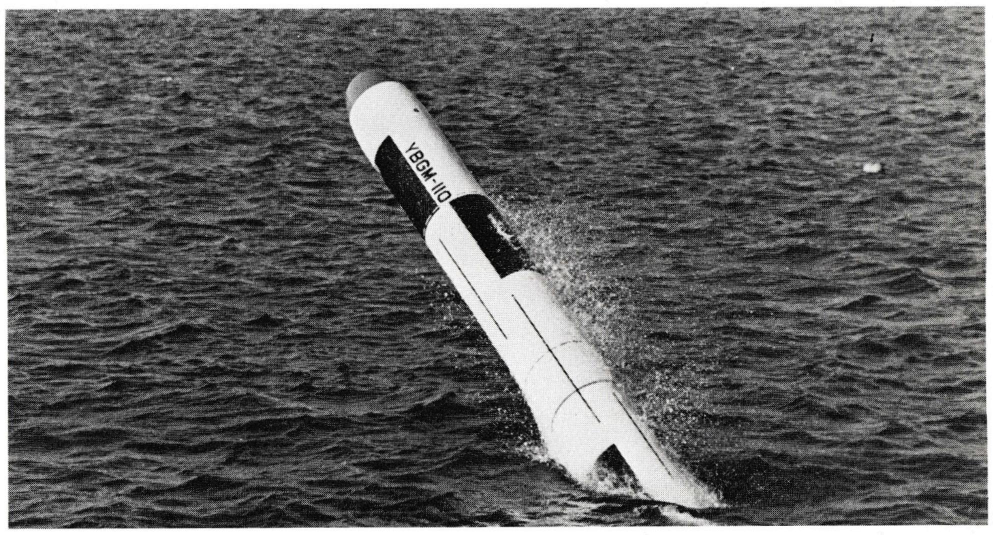
The PNE and TTBT agreements must still be ratified by a two-thirds vote of the U.S. Senate. However, the U.S. and U.S.S.R. have both informally observed the TTBT since the original March 31 deadline.

Meanwhile, the SALT talks still go on. Now in its second edition, SALT is the attempt of the two nations to limit the development of new weapons and the production of existing weapons.

From the beginning, SALT progress has been impeded by inequalities in the two nations' technologies and stockpiles; obviously, neither side is eager to freeze its inferiorities into law.

So the SALT negotiators are left to sort out interlocking complexities among such concepts as throw-weight, accuracy, launcher numbers, and detection, not to mention the differing geographies and perceived needs of the two countries.

SALT I resulted in two agreements, one on offensive and one on defensive missiles.



A Navy cruise missile test vehicle emerges from the Pacific after a torpedo tube launch from an underwater test rig off southern California.

The former froze deployment of offensive strategic missile launchers except for sea-based ones. Ceilings were placed on sea-based launchers and it was agreed they could be built as long as land-based ones were removed from stockpiles, on a one-for-one basis. The Soviets were allowed more launchers (2,358 to 1,710), but were not allowed to replace old missiles with their newest and most powerful model, the SS-9. At the time of the agreement (1972), the Soviets were thought not to have the capacity to place more than one warhead on each missile. The U.S., on the other hand, had MIRVs—multiple, independently targetable reentry vehicles.

On defensive systems, SALT I yielded the Anti-Ballistic Missile (ABM) System Treaty, which limited each side to two ABM sites. The two nations later reduced that number to one. (The U.S. has deactivated its one site, while the one in the U.S.S.R. remains operational.)

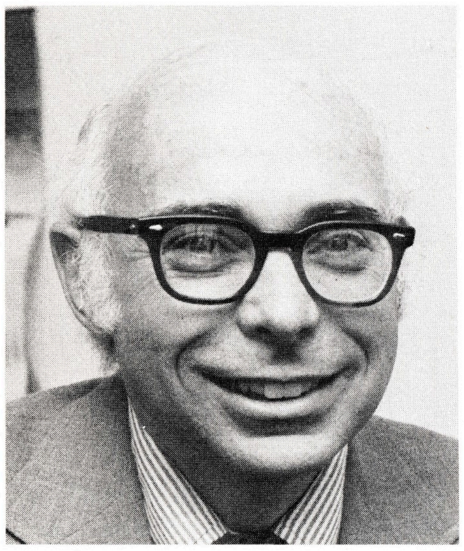
News reports indicate that the completion of SALT II is being delayed in part by disagreement over the cruise missile.

A cruise missile differs from the ballistic missile in that it does not leave the atmosphere. It is essentially a pilotless airplane that guides itself by responding to changes in the earth's terrain. This and other factors make radar detection difficult. It is also small enough to be launched from anywhere, including naval torpedo tubes, a fact which complicates detection. That, in turn, complicates verification of compliance with a possible treaty limiting its numbers.

The Russians would like to count the U.S. cruise missiles under the strategic ceiling.

In return, the U.S. is reported to be seeking restrictions on the new Russian bomber known as the Backfire. The U.S. argues the Backfire can be considered a strategic (i.e., long-range) weapon if it is allowed to re-fuel in flight or at a Soviet Arctic air base. If the Backfire is not considered strategic, it cannot be covered by SALT.

At any rate, if SALT II does yield a treaty, that treaty is expected to flesh out the general, less formal agreement arrived at by chiefs of state Brezhnev and Ford at Vladivostock in 1974. That agreement set the maximum number of strategic delivery vehicles for each side at 2400, of which 1320 could be MIRVed.



Landauer in D.C.

Lab people abound in Washington. Some are with private firms, others—either former employees or current ones on leave—are with ERDA and other government agencies.

Weapons program veteran Joe Landauer just returned from two years at the Pentagon, where he was advising on arms control matters.

In an interview back at the Pentagon, Landauer reflected on life in Washington.

"It's a madhouse," he said. "You're expected to respond to new situations instantly. It's a far cry from the reflective, relatively unhurried atmosphere at the Lab. I feel I'm working much harder here.

"The support levels are much lower," he said, noting that his office has two secretaries for seven people who spend most of their time creating paper work. "Most of government work is coordination," Landauer points out, and that takes paper work.

"It's also much less pleasant here," he said referring to the physical surroundings.

The Pentagon is drab and stifling. The offices are furnished inelegantly. The circular miles of hallways are distinguishable only by the numbers on the doors, and the numbers are incomprehensible. Landauer is someplace behind 4B748.

On the other hand, there are lovely rolling hills surrounding the Pentagon on which Landauer is able to jog at noontime just as he did at the Lab. Once you're inside the maze, though, that greenery is just a memory.

Despite it all, Landauer didn't dislike his tour. "My family likes Washington, and it has been interesting and fruitful for me and, I hope, for the DOD," he said.

"There's lots and lots of action, and a new idea does get a wide hearing, and that's exciting. On the other hand, government works by consensus, and it's hard to get any remarkable new action," he said.

It's partly because of the need for new ideas that Landauer was looking forward to returning to the Lab.

"I think two years is about tne right length for anyone," he said.

The military at Livermore:

Unusual assignments for career soldiers

Lyle Cox (left) with Major Bob Harter.

It's an unusual assignment, particularly for a career soldier who just a little more than a year ago was serving with an infantry unit in Alaska.

But Major Bob Harter doesn't mind spending part of his Army career at Livermore designing nuclear weapons. In fact, Harter, who has a masters degree in nuclear physics, is delighted.

"I'm extremely satisfied," says Harter, who began a two-year tour of duty in August 1975 as a weapons designer in B-Division. "This is a fantastic place. I could spend years here learning this business."

Harter is just one of some two dozen active duty officers currently assigned to the Laboratory by either the Army, Navy, or Air Force. While continuing their military careers, they have been engaged in a wide variety of research projects as associate members of the Laboratory's professional staff.

Some are working in the Lab's physics department. Others are in chemistry, or mechanical and electronics engineering.

They have come to Livermore as a result of separate agreements the Laboratory has with the three services. Under these agreements, each service has allotted a certain number of slots for technically-qualified officers to serve here as Military Research Associates (MRAs).

According to Lyle Cox, who administers the program for the Lab, each service nominates officers to fill these slots. Prospective MRAs must first be accepted by the Laboratory before they can be assigned here by the services. Normally, tours of duty run for two to three years.

Cox said that once an MRA joins the Lab he is treated like a member of the professional staff. Assignments to specific research projects, he said, are made by the Laboratory. Usually the MRAs are given the opportunity to pursue research in areas in which their services have a direct or general interest.

For example, said Cox, the Air Force is interested in laser technology and currently has a number of its officers assigned to the Lab's laser fusion and laser isotope separation activities. The Army Corps of Engineers, on the other hand, is involved primarily in the Lab's applied energy programs. That is an outgrowth of its original interest in the Plowshare program.

But the main interest of the services has been—and continues to be—in the nuclear weapons R&D program.

One former Navy MRA, for example, did a major part of the nuclear design work on the warhead for the Polaris A2 missile. Another was executive assistant to the project scientist for an elaborate underground nuclear vulnerability test.

Currently Air Force Lt. Michael Summers, a mathematician, is at work in A-Division developing weapons codes for the new CDC STAR computer. Another Air Force officer, Cpt. John Carson, is assigned to D-Division where he is currently involved with nuclear and non-nuclear effects and vulnerability.

"The knowledge I'm gaining here can be directly applied to related programs at my next assignment, the Air Force Weapons Laboratory," explains Cpt. Carson.

One of the payoffs from such an assignment is that it provides closer communication between civilian scientists who design the weapons and military officers who may have to use them.

Says Lt. Cmdr. Duane Stratton, a 17-year Navy veteran who has been working here since 1973 as a weapons systems analyst:

"I think my experience in the Navy can help give the scientists and engineers I work with a better insight into the needs of the potential users. That way they can look at their design work from the military point of view.

"At the same time, my work here in the Nuclear Explosives program will enable me to carry back to the Navy some idea as to how nuclear weapons are conceived and developed at Livermore."

Many credit Dr. Edward Teller as being one of those who greatly influenced the Laboratory's decision to participate in the military research associate program.

Noting that "the future of the Navy depends on novel developments," Teller years ago argued that the Navy could lose control over its future unless its officers had "expert knowledge in the relevant technical fields."

Although Teller's remarks were directed at the relationship between the Navy and the Laboratory, their meaning is applicable even today to all of the military services.

"The way I see it," observed Major Harter, "the military is involved in procuring weapons. That means it needs officers who are not necessarily pure scientists but who have the technical background to understand exactly what scientists are talking about when they come up with new ideas for weapons systems."

Cox said that since the program's inception in 1953, some 115 military officers have completed tours at Livermore as researchers. He noted that the experience the MRAs get here and at other government-funded laboratories provides the services with a nucleus of highly skilled officers who are equipped to handle a variety of technical management assignments.

Some go on to the DOD's own research facilities, or to management positions in service headquarters, the office of the Secretary of Defense, or in ERDA headquarters.

"There are many outstanding examples of MRAs who have advanced to senior national positions after leaving the Laboratory," Cox said.

"Major General Ernest Graves, who is now with the Army's office of the Chief of Engineers, formerly was Director of ERDA's Division of Military Application. Rear Admiral John Beling, who once headed the Navy's Office of Atomic Energy, has since retired and is a senior staff member of the Office of the Secretary of Defense. And Major General Jasper Welch is Chief of the Air Force's Office of Studies and Analyses."

And last year, said Cox, President Ford named Thomas C. Reed to be Secretary of the Air Force. Reed was an Air Force associate at Livermore from 1959 until 1961.

Popping the 'Strangelove' myth

It seems to some a strange profession, this business of designing nuclear weapons. Even if the old Hollywood 'mad scientist' image has disappeared, the public discourse is not always friendly: *Unquestioningly funded members of the mighty military-industrial complex blithely pursuing their own deadly game with the Russians, equally unconcerned about the effects of nuclear war and the diversion of public funds from domestic needs.* The image, if not general, is widespread.

Even the less critical are curious. What moves one into so grim a career? What satisfaction can be derived from designing instruments you hope will never be used? What's it like to always be involved in work that you can't discuss with family and friends?

Such questions posed to the scientists and engineers themselves bring responses ranging from uncomfortable one-word answers—indicating writer and subject just aren't on the same wave length—to open, discursive reflections and anecdotes.

In content, the answers show some definite patterns and a few dissagreements.

Entry paths to the career form one of the patterns. Nobody *Newsline* talked with began his career with a specific desire to do weapons work. Most began only with a specific desire to get a job, many preferring applied physics to campus work.

One young physicist in B-Division had been teaching at a small college in the Midwest.

"From 1970 to '73—the period I was there—the enrollment dropped from 1300 to 700," he said. "I had one class with only one kid in it."

Shrewd analysis of these figures led the young physicist to question his job security. He had a computer background and a desire to get into applied physics, and the step to Livermore was a natural one.

For another B-Division scientist who was completing grad school in that period, the first job offer was from Livermore. He took it not because it was in weapons, but because it was an opportunity to settle down—rather than do post-doctoral work—and because one didn't assume there would be swarms of offers coming in a tight job market.

Among Lab veterans fewer seem to have been motivated by economic conditions, but no more seem to have been particularly looking for weapons work.

Typical is John Kury, now manager for non-nuclear ordnance but for years involved in nuclear work. He came here in 1953, as part of a group of people then finishing their doctoral work at Berkeley, and helped start the Lab's chemistry department.

"Weapons hardly entered in to your considerations," he said. "When you start, you don't know anything about weapons. And at that time you didn't really differentiate on political or social questions."

Clearly one reason people don't seek out weapons work is that no one is exposed to weapons physics or engineering in school.

The only man *Newsline* talked with who came to the Lab because he wanted to do weapons work was Jack Rosengren, a former associate director now doing private consulting in Washington.

"I had been working in the aeronautics industry and I did some work on reactors," Rosengren said. "I came to believe that weapons was at that time (1957) a controlling technology. It was really just getting started, and it had great promise."

Whatever their reasons for entering the field, none of the people *Newsline* spoke with had any regrets. The veterans did know of people who had left weapons work, but nobody seemed to see occupational changes as more frequent in weapons work than in other fields.

The comments of Bill Nellis, a young B-Division physicist, were typical.

"I like it," he said simply. "It's certainly exotic. You can think about regimes that other people don't get to consider." Nellis has been involved in designing experiments on equations of state at very high pressures.

Although he misses working in an actual laboratory environment, Nellis said the Lab's system of focusing physicists on design with computers creates a great learning opportunity through contact with the other specialists who fabricate and analyze the actual experiments.

A colleague, who says he puts in 60 to 80 hours a week, said, "The job is technically very interesting, and there is something happening all the time. I really enjoy that."

Most of those interviewed have given more thought to the political and moral issues surrounding nuclear weapons since starting here than they did before. To a man they have come to believe strongly in the work of the Lab.

"To work here," said veteran metallurgist Phil Landon, evidently correctly, "you must believe in nuclear deterrence."

"Regrettable necessity" was the phrase used by Marv Gustavson, assistant associate director for military systems. "One regrets having to spend his time doing this rather than something else from which we might see more direct evident gain or pleasure for society.

"But we all tend to believe that only by having some reasonable strength can we expect anything like tranquility or to continue to exist as free men," he said.

Steve Cochran, a physicist just a couple of years off campus, said, "If you're going to make the first bomb, that's one thing. I can understand how it had to be done during the war, but it is a bigger moral question.

"But if you start from the fact that there already are bombs—and that there will evidently continue to be—then (1) you want competent people making them, and (2) you've got to remember that you're not necessarily going for more destruction. You're trying to make them safer, for example, and that's very laudable," Cochran said.

Even beyond the long-term need for weapons work, the interviewees were largely united on their specific concern about the short-term: the belief that the current American level of effort on nuclear weapons may not be large enough to keep up with the Soviets. "It's particularly frustrating in the realm of R&D," said John Kury, "because it costs so little relative to total systems cost. It just makes no sense to hold back in light of what we see the Soviets doing."

The specific judgment that if current trends continue, the Soviets will be in a dominant position by 1985 receives widespread acceptance.

Such strong judgments on so hot a political issue raise the question of the relationship of weapons people to a not always friendly political climate.

George Miller, A-Division physicist, said, "I have no qualms about talking with people about these things. I enjoy discussions; but I find most people have closed minds."

Miller, who was on campus until 1972 said, "People in academia have a certain point of view because they see the Soviets and Chinese as individuals, which is different than thinking about governments."

Miller came to the Lab partly at the urging of former graduate school colleague Bill Shuler, who had preceded him here. "Once I got here and could see both sides, I became convinced of the need for more weapons technology," he said.

Other scientists are evidently less combative than Miller. "I don't go telling anybody what I do for a living," said one. "For one thing there are always some 'kooks' out there."

Young and older alike see their profession as fairly low in prestige these days, but most seem not especially bothered by that.

Whatever their relationship to society as a whole, none of those interviewed reported any problems within their own families. While one noted that he had heard vaguely about problems within families with college-age children during the recent period of campus unrest, it was clearly not a subject pressing on the mind of those interviewed.

Even the classified nature of much weapons work is no problem for most. "It used to be worse," said one veteran. "Years ago it was questionable whether you could even say so much as that you were working, say, on Polaris."

Most said the problem in communicating with family and friends is not classification but the technical nature of their work.

However, one physicist did express frustration about not being able to communicate with other physicists.

"I think I have been involved in some neat experiments," he said, "and I would like to talk about them."

Pressed to name the worst thing about their profession, nearly all of those interviewed had to think awhile, then came up with work-a-day responses far removed from any philosophical dilemmas. The only gripe mentioned by more than one was "the computers," or more commonly, "the (expletive deleted) computers." The references were mainly to down time (when a computer isn't working) and lack of capacity.

Few saw job security as a particular problem.

"I don't think weapons work will disappear," was one typical comment. "It just doesn't seem to be that kind of world."

Of some concern, however, is the possibility that the opportunity to test may disappear. Although most see that as unlikely, they know that it did happen once—in the 1958 to 1961 U.S.-U.S.S.R. moratorium.

Several said fairly flatly that they would not work in a program that did not allow for tests.

"Tests are the all important thing," said one. "The excitement is in comparing your theoretical models with what actually happens."

Said one veteran, "There are always surprises. We found out in 1961 (when the moratorium ended) that we had strayed. And there are still things that can't be modeled."

Talking about trying to substitute computers for tests, another physicist said, "A computer only answers questions, it doesn't tell you what questions to ask."

Several of the scientists said that even if the weapons effort is cut and they lose their jobs, they would have hopes of remaining at the Lab.

"The Lab is flexible," said one. "Where I used to work, if management lost interest in a subject, the people involved always had to leave. I guess that was because the projects were long-term, and it would be difficult to step into another one in the middle.

"Here though, a lot of the projects are new, like in energy, and there aren't any established specialists," he said. "A weapons scientist might be able to step into one of those. I'm not worried about the long term."

Does the inability to further one's reputation by publishing lock one into the Lab?

"I don't think there is any problem," said one physicist. "I've had offers from several firms not in weapons work. When I was in recruiting I told people that outstanding work is recognized nationally. There is enough unclassified work and enough communication."

One young physicist told of having written five to eight papers since coming to the Lab, but all were on subjects he had been working on before coming here.

"I think I could go back to academic work now if I wanted to," he said, "although in a couple of years it might be a problem. Some people take the time to keep those options open, but I don't really worry about it."

In fact, another young physicist said one of the things he especially likes about the Lab is the lack of pressure to publish. He takes advantage of it.

Anyway, nobody is talking about leaving the profession.

In B-Division, which hired a sizeable number of new physicists in the early 1970's, none of the young people has left. And young people interested in entering the profession seem to be plentiful.

Bill Nellis, who is B-Division's recruiter, said "There just doesn't seem to be any problem. We get a very high caliber of people. Maybe it's just the tight labor market."

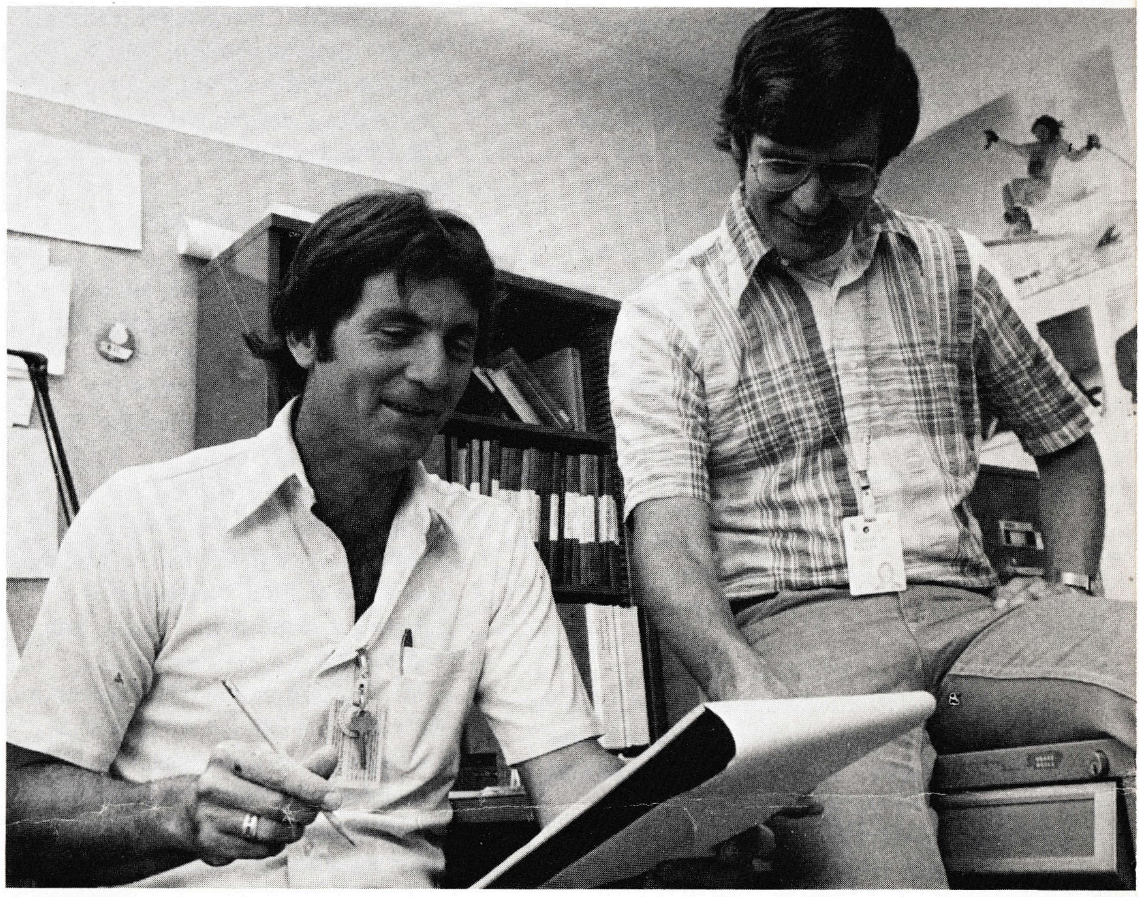
Those who enter find a profession that has changed greatly in two decades.

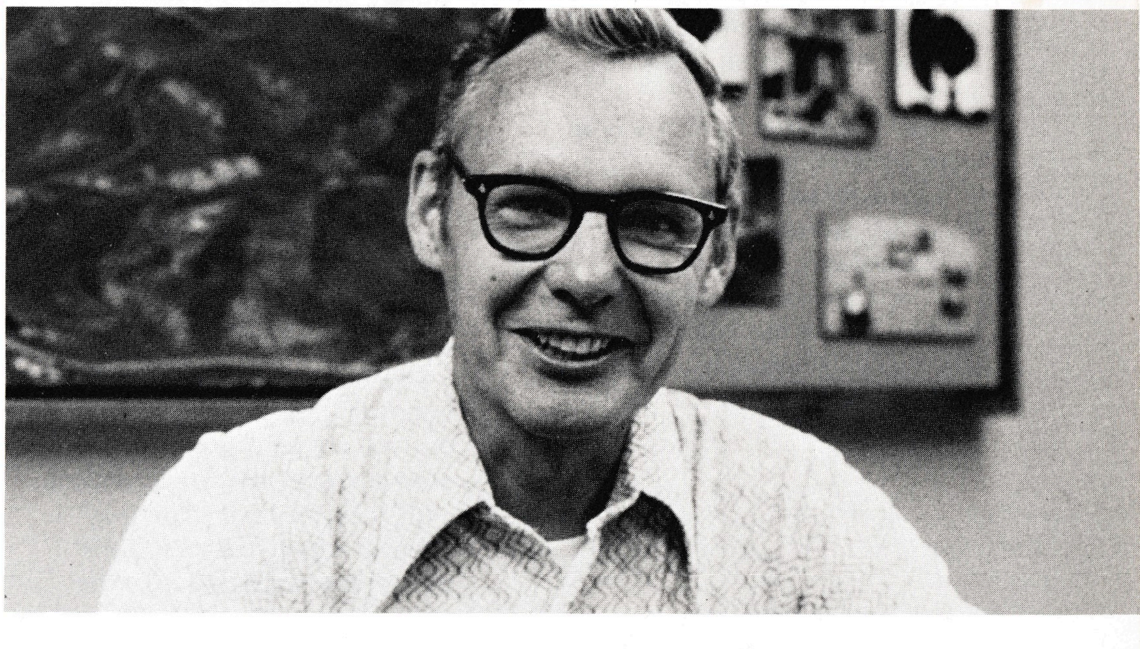
More than one veteran was willing to say that it used to be more fun—when a whole division would ship out to the Pacific for a test shot; when nearly everything had to be done by experiment, and the role of computers was very limited; when the money was plentiful; when the public was behind you 100 percent.

But it also used to be more taxing. More than one marriage was ruined by the long absences from home, more than one ulcer caused by the cancellations of Phase III's before they got to the stockpile.

It's all more routine these days, less glamorous, perhaps.

But the challenge remains. In some ways it has intensified as nuclear research has progressed and all the easiest problems have been solved. As one young physicist said somewhat wistfully, "You can't do the back-of-the-envelope stuff anymore."





Top: Physicists Bill Shuler (left) and George Miller, college friends who came to the Lab a couple of years apart. Center: Steve Cochran, also a physicist. Bottom: John Kury, a charter member of the Lab's chemistry effort.

TELLER

America's most persistent and impatient scientific innovator

This issue would not be complete without devoting an article to this man's contributions to the weapons program. At various times since the Laboratory was formed until his retirement last year, Edward Teller had to serve as salesman and spokesman as well as scientist in helping to launch and then provide the driving force behind LLL's weapons effort. His story is told in part with his own writings and in part by his colleagues.

Historians will credit the old Atomic Energy Commission as first among the government agencies which nurtured the once fledgling computer industry into its present robust adulthood.

For a quarter of a century the Commission held out lucrative contracts for the most brilliant innovators and let it be known that no foreseeable plateau could slake its thirst for more computing power.

Behind the Commission's thrust stood a handful of technical advisors, men driven more by a confidence in progress than by any certainty of what the future held.

And the most confident of them was Edward Teller.

Teller is most widely known to the public as the inventor of the hydrogen bomb, a distinction he rejects as being too simple a synopsis of a long, complicated effort.

That he did have a decisive role in untangling the bomb's tough theoretical physics is accurate. Nevertheless, to concentrate on that dramatic project is to miss totally the role Teller played—and continues to play—anywhere he has practiced his profession.

He is America's most persistent and impatient scientific innovator.

On his H-bomb work, Teller once wrote:

"Ulam had shown that our original ideas were unworkable...

"I approached the problem by attempting to free myself entirely of our original concept."

Anyone who has ever tried to purge his mind in favor of a fresh start knows how easily the human mind gets stuck.

"That done," he routinely continues, "it soon became obvious that the job could be done in other ways."

In 1952, a Pacific test put the U.S. on the road to thermonuclear superiority.

Teller, however, remained unsatisfied.

"It was an open secret, among scientists and government officials, that I did not agree with Norris Bradbury's administration of the thermonuclear program at Los Alamos...

"I knew that science thrives on friendly competition, on the fostering of different points of view, and on the exchange of ideas developed in different surroundings. I knew, too, that a single group of scientists working together can easily become fascinated by special aspects of a development to the neglect of other hopeful approaches."

With the help of E.O. Lawrence, Teller mounted an intense selling effort in Washington, an effort which resulted in the 1952 opening of the Lawrence Radiation Laboratory in Livermore.

He was determined that the new Laboratory would not work for minute refinements of Los Alamos designs. It would try novel—in some cases, sharply unorthodox—ideas. It would innovate.

Teller's recruiting, principally at UC Berkeley, assured success in that sense. He took no weapons experts.

"We were pretty naive in the weapons business," says Sid Fernbach, the Lab's computer chief and one of Teller's originals. "But it was a bright and daring group ready to try anything and that led to some very original dimensions in weapons design."

Perhaps that's one reason that nine out of ten U.S. strategic warheads were designed here.

Even today Teller continues to press colleagues and government officials to chance the new and daring. He has harsh words for work he considers "not novel."

And Teller himself leads the way, frequently jolting colleagues away from the safe-and-sane approach with seemingly outrageous suggestions.

Spurning the "self-sufficiency" notion in energy research, Teller instead has proposed fashioning strategy around a goal of making the U.S. an oil exporter within a decade.

"Without trying," he boomed at his retirement ceremony last year, "and without occasionally overextending yourself, you will get nowhere."

As expected, retirement meant nothing to Teller. Since June, 1975 he is known to have unsnarled several theoretical snags in the Lab's most futuristic weapons project.

"He has just a smashingly powerful intuition," says physicist and close colleague Lowell Wood.

Wood remembers one incident that tells much about that fabled intuition. While Wood was a graduate student at UCLA, a scientist reported synthesizing a stable compound of two so-called noble gases, gases scientists previously had believed could react with nothing.

Teller visited UCLA a few days later. No details of the synthesis had yet been released. He was asked about the reported discovery.

"For two hours he speculated about it," Wood recalls. "He explained the nature of the new compound, its chemistry and physics. Then he predicted what other noble compounds could exist and which could not."

Astonished onlookers commented that no one had ever known of this before.

Teller's response: "Someone should have known."

Later, Wood spent a year in the laboratory trying to determine whether or not Teller's theoretical sorting of the unknown compounds into possible and impossible species was generally correct. It was. In every case.

That incident also explains the basis of an old story.

In the early days of the Manhattan Project, so they say, program leaders were adrift on how to begin. Just the number of preliminary studies posed a barrier. The only thing to do, they concluded, was to form several work groups and get at it.

One organizer, however, had a faster solution. His suggestion: Put Teller alone in a room and make him guess the answers.

During the years of the Atomic Energy Commission, Teller played the ever-present gadfly, hurling down challenge after challenge in a tireless campaign to squeeze more useful applications out of the atom.

It was not an easy selling job. Teller, in his *Legacy of Hiroshima*, blames the Hiroshima bomb drop, an act he believes was unnecessary and unwise. The atom's fiery performance that day, he says, chilled the American public on nuclear technology for a long time to come.

He quit his job as Laboratory Director so that his hard hitting and sometimes sensationally reported speeches defending nuclear technology would not draw critical fire on the hunkered down AEC.

His every proposal brought a battle. Some he won, some he lost.

Occasionally he went on the defensive, trying to block some measure he felt would hamstring scientific innovation. Outcomes on that front also were mixed and there were periods when Teller is said to have fallen victim to severe depression.

John Morse, former deputy undersecretary of defense, recalls a day when he tried to spring Teller out of an ill mood by saying that most of the proposals the two men had pushed before the AEC had eventually been adopted.

No, Teller insisted, many or most had been failures.

"I went home," Morse says, "and listed 18 such programs in just 15 minutes. I went to the files the next morning and confirmed that 17 of the 18 were well established. The 18th was Plowshare and that too will be adopted one day. It takes time for people to come around and see what they have."

Teller always bounced back from his spells of melancholy, perhaps as soon as he realized such bouts take up time. "He's impatient," says Lowell Wood. "He's exceedingly aware of the fact that life is short and he's not interested in wasting time."

That attitude explains why a man known for his classic charm and grace is remembered by some as irascible and abrupt.

"I've seen him short with people," Wood says, "but they were people who were babbling just to have the experience of babbling in the presence of a great man.

"He'll suffer along silently through one or two inane remarks but more than that and he'll suddenly stand up and say, 'Thank you very much; I've enjoyed our talk,' and show you to the door."

Even those with important business have Teller's ear only until they complete the transaction.

"When you talk with him you're aware that he's sitting there mentally aquiver," Wood says. "It's as though he's saying: 'Yes, yes. What's next? Say something interesting or let's be done with this and I'll find something interesting somewhere else.'

"That makes most people extremely nervous and they know that if they leave a ten-second dead space he'll say: 'Well, I think we've come to the end of our conversation. Thank you for coming by.'

"So some people just keep talking, trying to fill in all the normal dead space. It comes out nonsense and he shows them the door."

A glance at Teller's schedule confirms that he's well advised to keep things moving. His secretary fills up his weekends right along with the weekdays; there's no dead time for catching up.

One way to avoid lost time is to plan. For example, Lowell Wood found this note on his desk one Friday:

"Dr. Teller (who was then in Texas and on his way home via Los Angeles) will see you Sunday afternoon. He expects you to be fully informed and prepared to discuss wave power."

Wood is a laser physicist and the Laboratory has no wave power program. Nevertheless, "the emphasis there is on *fully* informed," Wood said. "If I show up and don't know some aspect of that subject, he'll say: 'I gave you three days warning; why don't you know about it?' "

Who can guess what Teller has in mind on wave power? Those who know him well say he carries partially completed puzzles in his mind for years waiting to come across the missing piece that could make the pattern useful.

It is Teller's astonishing ability to store huge volumes of data from all over the physical sciences and to forge new correlations from the scattered pieces that most impresses the computer expert Fernbach.

"The computer hasn't been trained to do that yet," he says, "but it's the only possible replacement for men like Teller."

Whether a computer-like mind or some less tangible gift lies at the root of his fabled intuition, it is a quality that has made him the personification of what many people fear.

His ideas come from a realm beyond the experience of most people. To Teller, a concept may stand out in the bold clarity of a Ringling Brothers billboard. He points and he explains. But many still see nothing more than the dim figure of the future lurking off in the fog. And they fear it.

"As a boy," he once wrote, "I enjoyed science fiction. I read Jules Verne. His words carried me into an exciting world. The possibilities of man's improvement seemed unlimited. The achievements of science were fantastic, and they were good.

"Today I do not read science fiction. My tastes did not change. Science fiction did. Reflecting the general attitude, the stories used to say, 'How wonderful!' Now they say, 'How horrible!'

"Still, it is through science and science alone that we can satisfy the urgent and justified demands of the world's needy billions."

"WE ARE VERY FAR FROM THE END OF INNOVATION IN NUCLEAR WEAPONS."

When Edward Teller retired in June, 1975, *Newsline* was already making preparations for this special issue. We asked Dr. Teller to comment on the need for further weapons work. This is what he had to say.

"We are very far from the end of innovation in nuclear weapons. In the years ahead it is especially important that these innovations occur in this country. The Lawrence Livermore Laboratory is the place we must count on for these innovations.

"Let me explain.

"Our national leadership is trying to reduce tensions, the chances of confrontations and the possibility of all-out war. What we have so far is hopes. We must guard against allowing ourselves to believe the hopes are a reality. The reality is for the distant future.

"In the meantime, we must assume the possibility of confrontations for a long time to come. If they occur, we must already have made the continuing innovations that will keep us strong enough to prevent the confrontations from turning into all-out war.

"Many in the Lab know there were always people, too often in the majority—and sometimes the majority even in weapons work—who resisted further development. They did not, and many today do not, believe further innovation is possible.

"When I returned to weapons work in 1949, I attended a meeting of weapons leaders that was held before the first Soviet test (in August '49). The question at issue was: Now that we have done everything in nuclear weapons, what do we do next? Two people mentioned the hydrogen bomb and got talked down. I kept quiet because I saw it was hopeless. Even after the Soviet test later that year it was hard to get people to work on the hydrogen bomb.

"We can easily fall into the same trap again.

"We need to explore new applications of nuclear weapons, and a neglected field is tactical warfare. We have never taken this seriously. What we need to do is develop real tactical weapons that fit into new situations and new surroundings. Nuclear weapons are not absolute. We need tactical weapons that compliment other tactical systems and provide greater overall fire power for a land army, for example.

"We also have to adapt our nuclear forces to the problem of proliferation. India now has a nuclear weapon capability, and others probably will acquire it. So the non-proliferation treaty is becoming shakier than ever. What happens when many countries have these weapons? To give us a tolerable position, we must be prepared with weapons of the right properties, quantities and availability. This will require innovation.

"Livermore has made the innovations in nuclear weapons and explosives for the last two decades. The people in this Laboratory must continue; I do not see any other source on the horizon. I know from experience that work in this field is never easy and it is sometimes extremely difficult. But it offers very special rewards. It can make the difference—the difference in favor of freedom and peace."

As the sun rose over the still Nevada desert a hydrogen bomb lay quietly...

beneath 5,900 tons of dirt and gravel at the bottom of a half-mile shaft.

Later that day the bomb would figure in one of science's most demanding procedures, an underground thermonuclear experiment. This event was named Chiberta.

• • •

At noon Chiberta was detonated and the resulting explosion created the extremes of pressure and temperature similar to those at the heart of the sun.

A few millionths of a second later the instrument package that had gone downhole with the bomb was a cloud of vapor.

But by that time the diagnostic instruments had captured the scene electrically and had sent it through 60 cables to recording stations above ground.

Among the records were 200 photographs of 200 instruments triggered by the blast. To most people they were 200 white streaks across as many graphs. But when studied by experts the data would tell a rather complete story about the way Chiberta had performed.

Obviously, the idea of such an experiment is to detonate a nuclear weapon, and then study what happened.

Not at all obvious is the way to go about it.

This is Chiberta's story.

The Chiberta device—or a load of carefully machined and precisely assembled components that would soon be the device—had arrived at NTS six weeks earlier.

In a remote, heavily guarded area inside a workshop that resembles a vault, a team headed by physicist Cal Wood began the assembly.

Eight days and 167 steps later the Chiberta H-bomb was complete.

An outside observer had expected to find the assembly of the hydrogen bomb a unique event filled with tense drama. It was not.

Though each step was carried out with precision—measurements checked and re-checked, surfaces repeatedly cleaned with alcohol—the process was remarkably like piecing together any other mechanical device. Most of the tools were those anyone would recognize—wrenches, pliers, screwdrivers. The atmosphere in the assembly area, though businesslike and orderly, was nothing like the brisk regime of an operating room.

Once assembled, the device was encased in its canister. It was a painstaking job that took three days, technicians making sure that the canister would align perfectly with the diagnostic package that would later fit above it.

The canister was then trucked across the desert to a three-story building next to the test shaft, arriving shortly after noon on Monday, November 25. Once the canister was in its temporary home, engineers and technicians gave the alignment another going over. Several hours passed as measurement after measurement was cross-checked. Physicists and engineers crawled around on the container's top, reassuring themselves that the bomb's position was perfect. Meanwhile, the mammoth diagnostic canister swung overhead, suspended on a cable the size of a man's arm. The cable disappeared through the roof and snaked over the boom of a crane seated outside the silo.

A sign nearby designated the "man-in-charge." For Chiberta that man was Earl Crooks, a veteran device systems engineer who spent about half his working days last year in Nevada.

Crooks would that day officiate at what test people call a "marriage"—the joining of the device and diagnostic canisters. The diagnostic canister is crucial to the entire experiment. It is outfitted with a number of detectors that are trained on the weapon below through long iron pipes once the two massive components are fitted together.

The number of detectors varies but a five-pipe diagnostic package is common. Each detector is aimed precisely at the weapon and measures one specific phenomenon: for example neutrons, x rays, or temperature. From this and other data physicists can calculate in great detail how the device functions.

After the canisters were joined the device arming and firing mechanisms would be checked and finally there would be a dry run to see that microwave commands from the control point 20 miles away would reach the device and set it off.

Crooks presided over the preparations like a major domo, hustling a finished crew away while beckoning the next one. As the alignment specialists moved out, the iron workers moved in. A dozen men dressed in coveralls and hardhats surrounded the device canister. Foreman Jim Sargent, a brawny man standing about 6½-feet tall, donned a headset. He would talk the 120,000-pound diagnostic package down over the device canister.

Sargent guided the piece slowly. The crew could hear the determined rev of the crane outside, its operator blind to all except what Sargent's directions allowed him to visualize. As the canister inched lower the men surrounding it edged closer. All placed their hands on its sides and shoved together; the huge canister rotated slowly.

Looking between the two canisters as the space between them closed, the outside observer saw the ring of faces change expression in remarkable unison: determination building to effort; anticipation giving way to concern; tension building. Finally, the canisters pressed against one another and giant bolts were wrenched into place. The "marriage" was complete.

• • •

There was no lunch break that day; someone went for sandwiches. Late that afternoon, after several delays, a dry run showed that the microwave command from the distant control point would indeed trigger the device. It was ready for burial.

Lowering the bomb to its final resting place and filling the shaft took three days. To prevent leakage of radioactivity, the shaft was filled with a carefully selected mixture of sand, gravel, and ash. As an extra precaution, the half-mile shaft was sealed in two places with thick asphalt plugs.

A last dry run on December 15 had again shown that the device would fire; that its buried instruments would work faithfully before they ceased to exist; that 200 oscilloscopes above ground would be triggered automatically at the right time; and that the shutters on cameras facing the scopes would open in time to record the 200 traces.

(An oscilloscope is a kind of tv screen across which an electronic streak races, looking like a line on a graph. The streak represents a measurement taken over a very short period of time.)

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It was 6 a.m. on December 16, the day the Chiberta event was supposed to go. But there would be no experiment that day. Buried instruments were reporting that one of the asphalt plugs was still hotter than its best-strength temperature.

Later that afternoon a review of the plug's cooling trend caused yet another day's disappointment. Some around the control point grumbled that this was being too cautious. Test Group Director Roger Ide did not see it that way because the containment of radioactivity in any test is one of the test crew's primary concerns.

At 4:45 a.m. on December 18, some 50 people gathered in a briefing room to hear a panel of ERDA test officials discuss that day's plan.

ERDA test controller Charlie Williams sat at the head of the table; he would make the day's critical decisions. Williams, who once had been the Lab's Test Group Director, is a tall, rangy man with the look of a Texas cattleman.

Briefing officials told the panel that the obstinate plug was now well cooled. The weather, however, was another matter. There are only a few wind conditions test leaders will accept for a firing. One is gentle wind out of the east. That morning it was fairly brisk and gusting out of the northeast. Briefers told the panel that in the event of a so-called venting (historically, an extremely rare occurrence during an underground test), radioactive fallout could hit a small town to the southwest.

But the weatherman said conditions were likely to change, perhaps within a few hours.

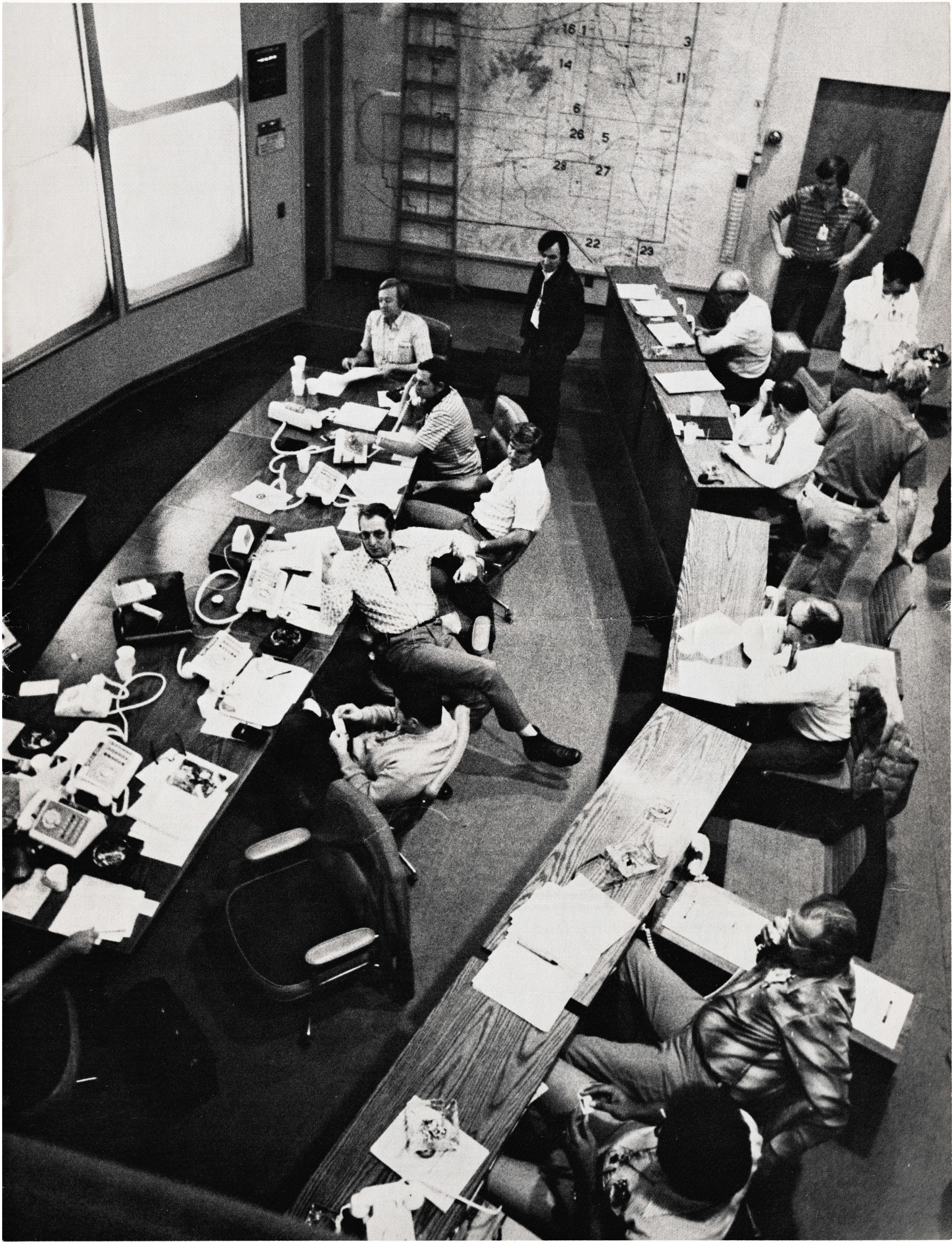
Larry Germain, then leader of K-Division and the panel's scientific advisor that morning, proposed that everything be prepared for firing in the event of a favorable wind shift. That meant evacuating the crew then preparing another shot some miles away. Removing that crew prematurely might forfeit a day's work in an already tight schedule—nothing to take lightly.

But Germain had argued persuasively that the winds, if and when they shifted, might remain easterly for only a brief time and then swing around further to blow out of the southeast. That, too, would mean no shot that day.

Charlie Williams sat grimly eyeing the charts. He was in a kind of poker game with the weather. The winds looked like they were changing. Was it a bluff?

"Okay," Williams said, "pull 'em out of there."

At that moment Earl Crooks and Ken Drezler, an employee of ERDA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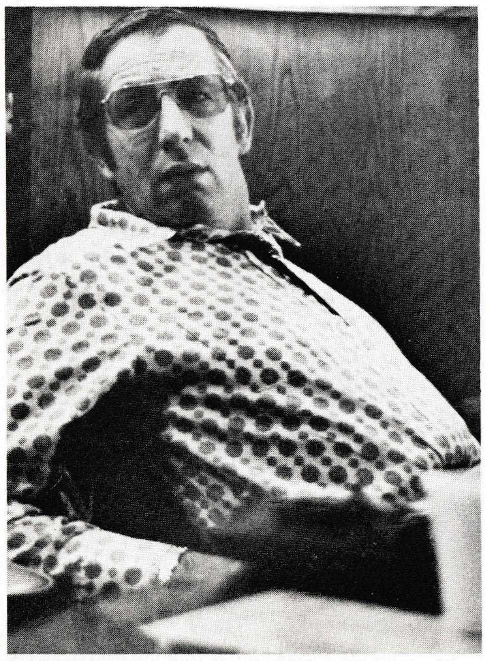
TOP: Charlie Williams
CENTER: Roger Ide (left) and Vernon Wheeler
BOTTOM: Earl Crooks (on phone)



electronics contractor EG&G, were already at ground zero waiting to arm Chiberta. An order to do that came at 6 a.m. (See "Can it go off by accident?")

But at 7 a.m. a weather report flashed on one of eight tv screens in the control room. There was little change. And so it went each hour until noon.

Meanwhile about 100 men waited idly. From the coffee pot to the vending machines to the control room, they wandered; from the lunch room to the control room to the men's room, they paced. Those who at 7 a.m. had spurned the local newspaper now re-read the Las Vegas shopper.

It was not the tense excitement one feels in a maternity waiting room. It was more like sitting around eight hours while one's car is being fixed.

The 2 p.m. weather report would bring decision, test veterans said. Another hour would place shot time too late for a daylight recovery of the data recorded near ground zero.

At 2:30 p.m. Charlie Williams stood facing a seated panel of tired, coffee-logged ERDA officials. There was little to discuss. Chiberta was rescheduled for the following morning.

Friday, however, was just like Thursday.

Saturday was not. Weather conditions suitable for a safe test prevailed.

At 12 noon on December 20, a 3,000-volt shock zipped downhole—and a half-mile down in the ground, the sun shone.

A rumble like an earthquake shook the control room but by that time the Chiberta device was gone. Left behind: a mountain of numbers.

A mop-up crew would return to ground zero and do a routine radiation check. The data would be packaged and sent to Livermore.

But already the attention of this strange physics laboratory in the dusty Nevada desert had shifted from Chiberta to experiments yet to come.

Earl Crooks, who had lived for weeks in a one-room, tile-floored NTS dorm unit, was gone before the shouting had stopped.

"They don't call me 'plus-two-microseconds-Crooks' for nothing," he smiled.

Why we test

Testing is very important to weapons scientists. They see it not as a luxury or a safeguard or the final step in a process (as in a manufacturing context), but as the very center of the scientific process. A nuclear test is really an experiment, and science without experimentation is like sports without rules.

So, testing cannot really be separated from the rest of the weapon R&D process. But because these experiments must be done underground in remote areas, a large effort with special techniques is required.

Because underground nuclear tests are costly and complex, their number is limited. So, the Lab uses large computers to calculate as much as possible about the performance of nuclear explosives. But computers can't do it all.

Harry Reynolds points to two big problems.

"The main thing right now," he said, "is that the basic science of nuclear explosives is not well understood, including basic facts that are necessary for computer calculations.

"On top of that, there is the fact that our computers—as big and powerful as they are—just aren't big enough to do all that is necessary," Reynolds said.

Rich Wagner, the Lab's associate director for tests who worked on the design side for years, says it another way.

"The Lab's job is to push into new areas of nuclear explosive design. If a particular approach can be accurately calculated, then that problem is solved. Then we have to move into a new area which can't be calculated, and that takes experiments."

And, he added, "I think that without testing the whole process would become a sterile exercise very quickly. It's really the difference between having to demonstrate that something operates in the way you predict and not having to do that demonstration.

"You just can't do anything that purports to be scientific in nature without doing experiments," Wagner said. "It's as simple as that."

Can it go off by accident?

Arming a buried device amounts to little more than plugging a cable leading from the bomb into an electrical outlet.

But what would happen then if someone back at the control room inadvertently sent the firing signal?

Nothing—because the arming party first sets an electronic lock which prevents current from entering the outlet.

The key to open that lock is a 10-digit number. Before hooking Chiberta to the firing outlet Earl Crooks had selected five numbers randomly, Ken Drezler the other five. A few minutes before firing time Crooks, by then back at the control point, would lock the microwave transmitter with his part of the code; Drezler would add his half. At shot time the 10 numbers would beam through the air, open the lock, and allow the signal to stream down to the bomb.

The use of the 10-digit code means that anyone wishing to try combinations at random in a deliberate effort to prematurely detonate the bomb would have to try more than 3.5 million combinations.

There are electronic gadgets, however, that can race through such a trial-and-error job in about six seconds. Therefore, NTS firing circuits accept only five mistakes; if the right combination doesn't arrive in six tries or less, the firing system self-locks.

Chiberta no long-shot

The winds that sweep the Nevada desert now blow little of the gambler's spirit toward NTS; Chiberta's success was hardly a long-shot.

More than a year earlier a precise mock-up—but with the nuclear parts made of dummy materials—gave physicists their first chance to check the computer's arithmetic on the ideas that would lead to Chiberta.

A nuclear weapon works only if nuclear materials meet one another under high pressures in precise configurations.

A powerful chemical explosive is what crushes a weapon's nuclear package to trigger the nuclear reaction.

The explosive's effect—the exact shape its force imposes—is a key factor in the outcome of a nuclear explosion. That's what Site 300 experiments test.

One does not easily envision using an explosion to put anything in a precise pattern. Nevertheless, it can be done if the pre-detonation arrangement is just right for the carefully shaped explosive force.

A computer can suggest such a promising arrangement and sophisticated experiments such as those done at Site 300 can test and refine the suggestion. Though hard for the layman to imagine, a carefully aimed explosion is quite an orderly affair.

Detectors placed inside mock devices at Site 300 film an electronic "report" of the way nuclear materials would travel on the squeezing frontier of the explosive's shock wave.

What the human eye might see as a helter-skelter jumble of flying particles is seen by electronic eyes as a controllable and predictable crushing together of a shell.

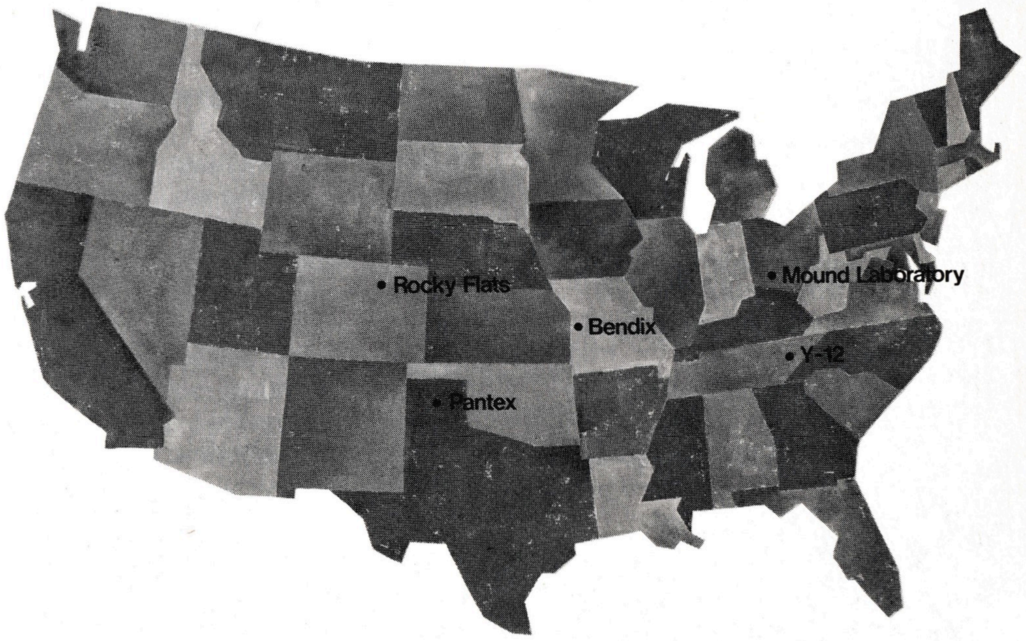
"Cut the time step short enough," said physicist Cal Wood, "and you can see order in anything. Watch a movie taken at 25 frames a second and you see only one event. Film the same occurrence at 2 million frames a second, as we do, and you're in a different world."

When scientists review the data with the computer's help they may adjust a new design's geometry to get what they think will be better performance. Then it's back to Site 300 for another check.

A new design may take several trips to Site 300 before researchers consider it ready for the Nevada Test Site. But because there are no nuclear materials to control, cost of a Site 300 experiment is just a fraction of that spent to stage an underground shot.

The road to Amarillo:

Working with the arms builders



Shown here are the five weapon plants in the ERDA complex that the Lab deals with. Run on ERDA contracts not unlike the Lab's, they build the warheads.

There is a group of some 20 people at the Lab that travels over a million miles each year—or about l,000 miles per week per person.

Not only that. They get to visit such places as the Texas Panhandle, eastern Tennessee and Dayton, Ohio.

These people are part of the unique ERDA structure which keeps the design and production of nuclear warheads in separate hands.

"That kind of structure can only work if there is an intimate relationship between the design labs and the production facilities," said W-Program Leader Bill Nelson. "We have that sort of relationship."

Under the ERDA structure, seven private corporations run seven government-owned production facilities. These plants, which employ some 18,000 people and receive about one-half billion dollars a year from ERDA, are responsible for building warheads for weapons going into the stockpile.

The approach differs considerably from that used in producing the other parts of weapon systems. These are built by companies under contract to the Department of Defense with a different contract issued for the production of each weapon, generally to the same firm which designed it.

Design and production of warheads, however, are placed in separate hands because of the need to centralize nuclear warhead technology development within the government.

The production facilities with which the Lab deals include Union Carbide's Y-12 Plant in Oak Ridge (Tenn.), specializing in uranium work; Monsanto's Mound Laboratory in Miamisburg (Ohio), near Dayton, primarily in detonator production; Rockwell International's Rocky Flats Plant near Boulder (Colo.), working with plutonium and beryllium; Bendix's Kansas City (Mo.) Plant, specializing in electronics, plastics and non-nuclear metals; and the Mason & Hanger-Silas Mason Pantex Plant in Amarillo, where final assembly is done, among other things.

About one-third of W-Program is directly devoted to liaison with these facilities, and two of its groups have full-time liaison duties.

The Production and Surveillance group is the well-travelled one mentioned above. It is responsible for overseeing every weapon the Lab is involved with, not only in production, but when it is disassembled or tested at some point during its life in the stockpile. (Disassemblies and tests are the major methods used to monitor a weapon's reliability. According to Nelson, "Whenever they take apart a weapon or test it, we are there.")

Nelson said the Lab—which has final technical authority during production—gets about 60 requests each month for deviations from the original design.

"The manufacturer may either say that they've found a better way to do the job or that it can't be done our way," he said.

When that happens, a member of the Production and Surveillance group is on the way—perhaps accompanied by somebody who worked on the design of the warhead—to resolve the problem.

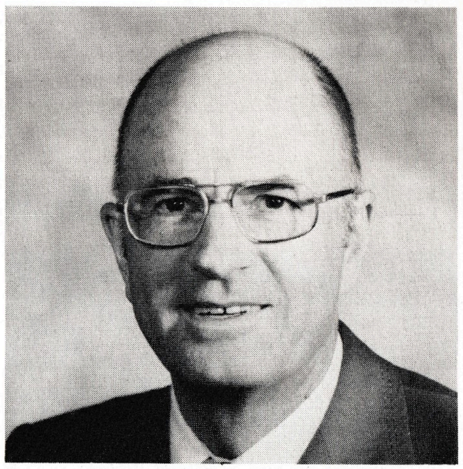
If disputes arise, the final authority rests with the manager of ERDA's Albuquerque Operations Office (ALO).

The manager there is aided on system-wide problems by a Weapons Advisory Committee now chaired by Lab Deputy Director Duane Sewell, and involving members of other laboratories. The Lab deals with ALO on a daily basis at all levels, said Nelson, who is the Lab's formal contact with that office.

The second group which formally deals with the production complex is the Special Materials Staff (SMS). Currently numbering five scientists and engineers, the SMS administers the acquisition of material the Lab has ordered for use here.

The SMS people—most of whom are Lab veterans chosen because of their experience—are also the Lab's prime administrative contacts with the production facilities for what is called "process development." That is the alteration of existing facilities and manufacturing techniques to prepare for the production of new weapons.

The goal of this effort is to minimize the cost and time it takes for a weapon to reach the stockpile. The idea is for the plants to be ready to start producing as soon as the design is approved for production. In other words, for Phase IV to follow Phase III as soon as possible.



Deputy Director Duane Sewell, chairman of the Weapons Advisory Committee.

Weapons Glossary

A guide to this special issue of Newsline

ABM: Anti-Ballistic Missile, a missile for attacking incoming re-entry vehicles

ABM Treaty: Part of SALT I; U.S.-U.S.S.R. agreement to deploy at most two ABM sites each

ACDA: The U. S. Arms Control and Disarmament Agency, an independent unit in the executive branch

B-1: Proposed U.S. strategic bomber

B-52: Current U.S. strategic bomber

Backfire: New Soviet long-range bomber

Ballistic Missile: A missile launched out of the atmosphere that reaches its target by unpowered trajectory

CCD: Conference of the Committee on Disarmament of the U.N.

Collateral Damage: In this context, unintended damage from a nuclear attack

Command and Control: The U.S. system for keeping complete control over nuclear weapons

Conventional: In this context, refers to non-nuclear warfare and weapons

Cruise Missile: A pilotless, warhead bearing airplane

Delivery System: That which carries a warhead or bomb to its target

Detection: The attempt to locate another nation's unfired weapons

Deterrence: The philosophy holding that nuclear forces must be designed to prevent war from occurring

Device: A nuclear explosive (generally used in the context of testing)

Equations of State: Mathematical descriptions of the way given materials behave under various conditions

Fission: Physical process in which nuclei split, thus releasing enormous energy; on most modern nuclear weapons a fission reaction is used to start a fusion explosion. Earliest nuclear weapons were entirely fission

Forward Based System: In this context, American nuclear forces in Europe and Asia

Fusion: Physical process — like that occurring on the sun — in which small nuclei fuse, thus releasing enormous energy

Hardness: In this context, the strength of a missile silo to withstand a nuclear blast

H Bomb: Fusion-based hydrogen bomb; as opposed to fission-based atomic bomb

Hydrodynamics: The science of the mechanics of fluids; crucial in nuclear weapons physics

IAEA: International Atomic Energy Agency, devoted to monitoring and regulating nuclear power and fuel

ICBM: Intercontinental Ballistic Missile

ISA: International Security Affairs, the Defense Department office that deals with arms control

Kiloton: Energy release equal to 1000 tons of TNT

Lance: Modern U.S. tactical nuclear surface-to-surface missile; Lab designed warhead

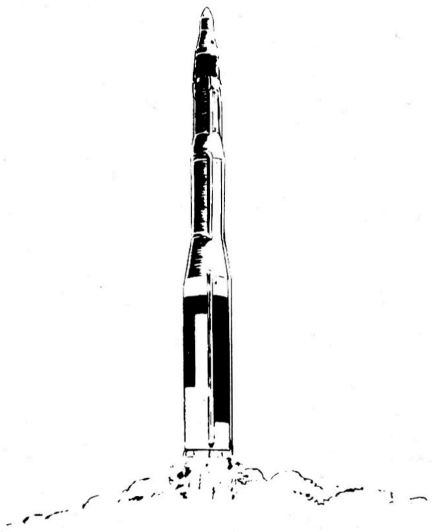
LTBT: Limited Test Ban Treaty, 1963 U.S.-U.S.S.R. agreement forbidding above ground testing of nuclear explosives

Manhattan Project: Crash World War II project to develop first atomic weapon for U.S.

MARV: Maneuverable Reentry Vehicle, a new delivery system that would allow a reentry vehicle to change direction to evade defensive missiles

Megaton: Energy release equal to 1,000,000 tons of TNT or 1,000 kilotons

Minuteman: Current U.S. ICBM; Minuteman III is MIRVed



MIRV: Multiple, Independently Targetable Reentry Vehicle, an ICBM with several warheads which may be aimed at different targets

Moratorium: 1958-1961 period when neither U.S. nor U.S.S.R. conducted nuclear tests

Ordnance: Weapons

Payload: Weight which a delivery system can carry

Perimeter Controls: System for keeping would-be terrorists away from stockpile weapons

Phases: First outlined officially in a 1953 agreement between the Defense Department and the old Atomic Energy Commission, the phases in the life of a nuclear weapon now number seven: I. Conception; II. Feasibility Study; III. Engineering and Development; IV. Production Engineering; V. First Production; VI. Quantity Production, and VII. Retirement

Plowshare: U.S. program on peaceful use of nuclear explosives

PNE: Peaceful nuclear explosive

Polaris: The first generations of U.S. nuclear-armed submarines (un-MIRVed); equipped with Lab-designed warheads

Poseidon: MIRVed and long-range U.S. nuclear-armed submarine

Proliferation: International spread of nuclear weapons

Radiation: In this context, the after effects of a nuclear explosion, the possible emission of harmful, invisible rays

Re-entry Vehicle: The part of a ballistic missile that carries the warhead back into the atmosphere

SALT: Strategic Arms Limitations Talks between U.S. and U.S.S.R.; SALT I limited some weapons deployment, and SALT II is now in progress

Silo: Housing for an ICBM

SLBM: Sub-Launched Ballistic Missile

Spartan: ABM missile; Lab designed warhead

Stockpile: All deployed weapons

Strategic: As opposed to "tactical," refers to large and long-range nuclear weapons

SUBROC: Submarine Rocket, a U.S. submarine-launched tactical nuclear weapon aimed at other vessels

Survivability: In this context, the ability of a nation's nuclear force to survive a first strike

System: The combination of warhead and delivery vehicle, and reentry vehicle and launcher where appropriate

Tactical: Nuclear weapons of relatively low yield and short range

Thermonuclear: Referring to fusion that occurs between small nuclei under intense heat and causes further fusions

Throw-weight: Payload of a missile

Titan: An early U.S. ICBM that is liquid fueled; now plays smaller role in strategic arsenal than solid-fueled Minuteman

TTBT: Threshold Test Ban Treaty, which, if ratified, would limit underground nuclear explosions to under 150 kilotons in yield

Verification: In arms control context, the process of checking on compliance with treaties

Vladivostok Agreement: 1974 Ford-Brezhnev agreement to try at SALT II to limit strategic weapons to 2400 per country

Vulnerability: Refers to the chances of a weapon being destroyed

Warhead: The explosive part of a missile

Yield: The energy of a nuclear explosive

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